INDUSTRIAL FUEL AND POWER

Papers and Discussions Presented Before the Affiliated Technical Societies of Boston

December 10 and 11, 1925

715 Tremont Temple
Boston, Massachusetts

THE AFFILIATED TECHNICAL SOCIETIES OF BOSTON

Fuel and Power Meeting

December 10, 1925

Morning Session

"Sources and Utilization of Fuels"

Dr. Ira N. Hollis, Presiding

Afternoon Session

"Requirements of Power in the Industries"

Dr. Samuel W. Stratton, Presiding

December 11, 1925

Morning Session

"Operating Practice"

Irving E. Moultrop, Presiding

Afternoon Session

"Industrial Power"

Frederick M. Gibson, Presiding

Evening—Annual Dinner

Subject: *"Domestic Heating"*

THE AFFILIATED TECHNICAL SOCIETIES OF BOSTON

Officers, 1925-26

Frederick M. Gibson, *Chairman*
Thomas S. Knight, *Vice-Chairman*
Frederic A. Eustis, *Vice-Chairman*
Alfred Kellogg, *Treasurer*
P. D. G. Hamilton, *Clerk*
J. B. Babcock, *Executive Secretary*

Program Committee, 1925-26

Lewis E. Moore, *Chairman*
Frank M. Gunby
Thomas S. Knight

Fuel and Power Meeting—1925

Committee on Papers

Charles T. Main, *Chairman*
Nathan Cheney
Nelson J. Darling
Edward F. Miller
Irving E. Moultrop

Committee on Finance

Chas. R. Gow, *Chairman*

Committee on Arrangements

M. K. Bryan, *Chairman*

Committee on Publicity

Maurice M. Osborne, *Chairman*
Frederick W. Bliss (Providence)

CONTENTS

Lawrence Press, Inc.
Boston, Mass.

Industrial Fuel and Power

Coal—The Basic Fuel

By F. H. Daniels

Vice-President, Riley Stoker Corporation, Worcester, Mass.

The object of this paper is to make a brief survey of the supply of fuel which is available to us in the United States, and to show the rate at which we are using these supplies. These fuels include natural gas, oil, anthracite and bituminous coal; and of course water power must be considered as a substitute for the fuels.

Natural Gas

Our supply of natural gas, once so plentiful, has been used with no thought of conservation, and as a result, to all intents and purposes, it is today practically exhausted. The use of natural gas is now a negligible factor in power production. Once we had so much of it that it was considered economy to leave the gas street-lights burning all day rather than to go to the expense of turning them off in the morning and lighting them again in the evening. This is merely one indication of how we threw away this natural resource. From many standpoints gas is an ideal fuel. Its chief advantage lies in the fact that it can be so intimately and accurately mixed with the air required for combustion. It is easy to see that two gases, such as natural gas and air, can be mixed much better than is the case with a liquid and air or a solid and air. Now that the natural gas has gone, it does no good to wish that we had it back again, and the only course open to us is to be economical in the use of the fuels that remain to us.

Fuel Oil

Next in order of importance comes fuel oil. According to the figures of the United States Geological Survey, the total oil production of the world up to 1925 has been about 10½ billion barrels, and the United States has furnished about two-thirds of this, or 7 billion barrels. An estimate of the petroleum reserve of the world has been set at approximately 40 billion barrels. A curve showing the yearly consumption of petroleum of the United States over a period of more than forty years is shown in Fig. 1. This is increasing

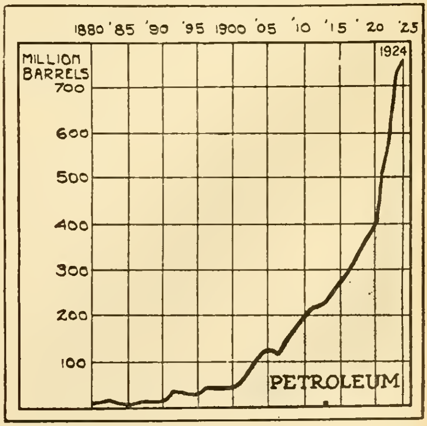

Fig. 1—Yearly Consumption of Petroleum in United States
(Courtesy of *Scientific American*)

so rapidly as to represent almost a second degree curve. In 1924 the consumption of petroleum was about 800 million barrels. The United States Geological Survey has made public a careful estimate of the oil reserves of this country. This shows that about 8½ billion barrels are still left available under the present methods of extraction. Of course, improved methods of recovery may increase the above figures very materially, and when the price gets high enough, there is no doubt but what the oil-bearing shales will be forced to give up their store of oil by means of new processes, but as yet oil prices are not high enough to justify the working of the oil shales. Up to date we have produced in this country about 6¼ billion barrels of oil, so

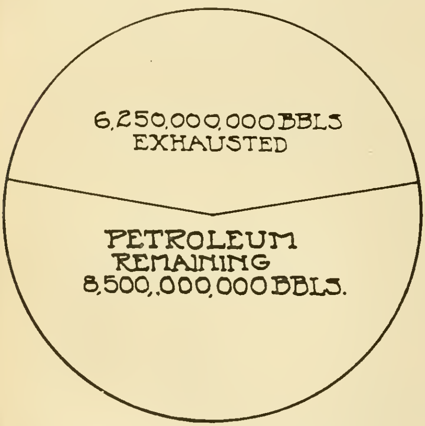

Fig. 2—Oil Reserves in 1924
(Courtesy of *Scientific American*)

this means we have used up about 42 per cent of our original supply. Figure 2 illustrates this condition.

Bituminous and Anthracite Coal

With reference to the available supply of coal, the story is quite different from that of oil. We have still left about 1,510 billion tons of bituminous coal, having used less than 1 per cent of our original deposits. We have approximately 17 billion tons of anthracite still in the ground, having used about 15 per cent of our original supply. There is also left practically untouched over 2,000 billion tons of lignite, not figuring at all on the peat deposits, which are enormous. This makes the grand total of bituminous, anthracite, and lignite reserves of the United States 3,527 billion tons. Figure 3 shows the present situation with

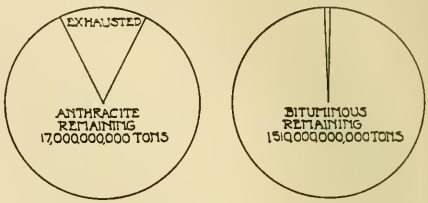

Fig. 3—Coal Reserves
(Courtesy of *Scientific American*)

reference both to bituminous coal and anthracite coal. It may be noted that on bituminous coal we have hardly made a dent, and on anthracite, there is plenty left.

Comparison of Coal and Oil Reserves

Let us assume that the 3,527 billion tons of coal still in the ground will average 10,000 B. t. u. per pound, and that the total available coal heat units can be calculated. This amounts to 70½ quintillion B. t. u.'s. Assume that the 8½ billion barrels of petroleum still untouched will average 18,000 B. t. u. per pound, and the total oil heat units in reserve can be calculated on the basis of 336 pounds per barrel. This amounts to 51½ quadrillion B. t. u.'s. A comparison of these two calculated figures shows that the ratio of the available coal heat units to the available oil heat units for this country is about 1,370 to 1, or 1,370 times as much coal as you have oil. At the present rate of consumption, the oil reserves of this country would last about twelve years. This figure is on the basis that the present rate of consumption does not increase and that all of the oil remaining can be found within that time. Neither of

these assumptions is true, but it indicates that the United States will become more and more dependent, as time goes on, upon importation of petroleum from foreign countries, with the corresponding gradual increase in price. As oil gets scarcer, it is very probable that the low temperature distillation of soft coal will be resorted to in order to eke out the supply, but the price of petroleum will have to go up considerably before this expedient will pay.

The United States Geological Survey estimates that out of the 8½ billion barrels of oil in reserve about 4 billion barrels consist of the heavy oils, with an asphalt base, from which fuel oil is derived after the naphtha, benzene, gasoline, and kerosene are taken out.

Production, Consumption, and Prices of Oil

Figure 4 gives a bird's-eye view of the petroleum situation for a period of the last ten years. The average price of Pennsylvania crude oil in dollars per barrel is shown, as well as variations in consumption and production of petroleum in barrels per month. It may be noted that every time consumption exceeds production, the price of oil goes up. During practically all of 1923, production exceeded consumption, and this brought the price of petroleum down until it was lower than at any time since the beginning of the war, except for the panic year of 1921. The reason for this over-production was the unexpected flow of oil from California and Texas. During 1924 the consumption was greater than the production and the result has been relatively high fuel oil prices. From now on these high prices must be the rule rather than the exception, and fuel oil will probably never again compete with coal for steam generation except in very special cases.

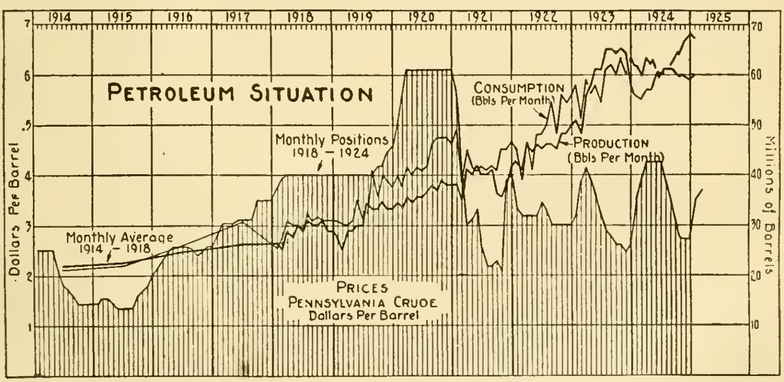

Fig. 4—Petroleum Situation for Ten-Year Period

The remainder, which consists of the lighter oils, having in general a paraffine base, is too valuable to use for fuel oil purposes. In other words, less than half of the available oil reserves of the country can ever be used for fuel oil, and as time goes on we will have to import from Mexico and other foreign countries more and more fuel oil for use in those places where we just cannot get along without it. We can get along, however, without fuel oil for steam generation in stationary boiler plants.

Water Power

The water-power resources of the United States are very large, but even if these were fully developed, they could not meet our present demand for

power. Unfortunately our water-power resources are largely located in the thinly settled portions of the country where industry has not yet been developed sufficiently to justify their use. Our chief supplies of coal, on the other hand, are located adjacent to sections of the country which are fully developed commercially. This accounts very largely for the leisurely way that we are utilizing our water power.

Where Coal is Found

Figure 5 shows the coal fields of the United States. This was taken from the circular on the anthracite coal situation issued by the United States Chamber of Commerce as of September 1, 1925. The anthracite fields marked "1" are located in a small section of Eastern Pennsylvania covering about 480 square miles. This is the only place in the country where hard coal is mined. Anthracite is first and foremost a household fuel, being used extensively in the New England States, New York, New Jersey, Pennsylvania, Delaware, and Maryland. The small sizes, which result from screening, amount to about 30 per cent. These smaller sizes are used for industrial purposes. Soft coal is mined in twenty-three states, and the various fields cover an area of about 458,000 square miles, which is 954 times as large as the anthracite-producing areas. Bituminous coal is generally thought of as not being used ordinarily for household heating. As a matter of fact, however, more people in this country heat their homes with soft coal than with hard. On the map the black areas represent the non-union fields, while the shaded areas show the unionized fields. At the present time, 70 per cent of all the soft coal mined comes from the non-union fields. West Virginia furnishes us the low-volatile, low-ash, semi-bituminous coal, while the high-grade bituminous comes from West Virginia, Pennsylvania, Ohio, Kentucky, Tennessee, and Alabama. A lower grade of bituminous is found in Michigan, Indiana, Illinois, Iowa, Missouri, Kansas, Arkansas, Oklahoma, and Texas. This region is the so-called "central competitive field." The sub-bituminous coals are mined in Montana, Wyoming, Colorado, Utah, New Mexico, Arizona, and Washington, and the lignites are found chiefly in North Dakota, South Dakota, Montana, and Texas.

Fig. 5—Coal Fields of United States

How and Where Coal is Used

Each year we burn about 2/3 of a billion tons of coal. This includes both bituminous and anthracite. The bituminous coal used is about 552 million tons and the anthracite about 90 million tons. Dividing this up by industries shows the following:

Industrial plants	33.5%
Railroads	25.0%
Domestic	16.5%
Coke production	13.0%
Electric public utilities	6.5%
Gas public utilities	1.0%
Bunker and export coal	4.5%

The average industrial plant does not recover as useful work more than 5 per cent of the heat energy of the fuel. The best plants recover more than four times as much. This industrial field is the one where large economies can be made in the use of fuel. The ordinary industrial plant may show an average efficiency of about 55 per cent, while 80 per cent boiler efficiency is possible. The margin here is large enough to justify the best thought of engineers.

Locomotives use about one-fourth of all the coal produced, and they are most inefficient. Not more than 5 per cent of the heat energy of the coal is actually delivered by the locomotive in drawbar pull. Improvements now under way in locomotive design and the possible electrification of certain of our railroads indicate that the waste of coal by the railroads will be stopped. Experiments on better combustion, economizers, superheaters, condensers, compounding, forced and induced draft, geared-turbine drive, etc., all show that progress is being made, but it will take a long time to accomplish much.

Next in order of importance comes the domestic consumption of coal. Here is the place where the booby prize can be awarded for the greatest waste. Poor construction, lack of knowledge, and neglect all combine to throw coal away. With just a little more intelligent care, it would be easy to save one-fourth of the coal that is now used in house heating.

The production of coke is fast getting on an economical basis. Only about 25 per cent of our coke is now made in the wasteful beehive ovens, and 75 per cent of the coke is now made in by-product ovens which recover all of the valuable by-products formerly thrown away.

In the electrical public utilities there is very little waste of fuel. Coal represents more than half of their cost of doing business, and as a result the pocketbook forces them to be careful. The great majority of the electrical public utilities have put in a lot of thought and spent tremendous sums of money to assure the economical use of coal. Eighty per cent average boiler efficiency is not out of the question today.

The gas public utilities use 1 per cent of all the coal mined. This is a surprisingly low figure. Modern methods of gas manufacture will recover 80 per cent of the heat value of the coal if you include the by-products which result as a part of the process.

Here in New England we actually pay out more in freight charges for bituminous coal than the cost of the coal at the mines. It isn't economy to buy any but the very best grades of coal, for who wants to pay for hauling a lot of ash and dirt? For the same reason, efficient burning of coal should be the first aim if we are to compete successfully with other sections of the country more fortunately located in reference to coal deposits.

For household heating, New England seems to be wedded to anthracite. The present strike in the hard coal fields is demonstrating that soft coal can be used for domestic heating and that it requires only a little more care and attention than anthracite. The low-volatile semi-bituminous coals of West Virginia are much better than the average bituminous coal that more than half the people of this country habitually use for domestic purposes. Anthracite should

be classed as a luxury fuel. It is not a necessity. Seventy million dollars a year is the extra amount that we pay in New England for the privilege of using anthracite. Laziness, prejudice, and ignorance are the three things which prevent the widespread use of bituminous coal for household heating in this section of the country.

The source of all our heat energy is the sun. It stored up for us in the ground during ages past the natural gas, oil, and coal. These things, once used, can never be replaced, and our only other recourse is to use the heat of the sun as available to us now. This can be done by utilizing the power of falling water. The heat of the sun will raise crops which in turn can be transformed into the alcohols, or perhaps even the direct heat of the sun can be concentrated and used in some form of heat engine. Our natural gas is gone; our petroleum is about half used up; it will take years of industrial growth before our water powers can be fully developed. For generations to come, coal must be the basic fuel. Whatever fuel you use, don't waste it by burning it carelessly. Even if you are not interested in what becomes of your children and grandchildren, conservation of our fuel resources is worth while to you. It pays to do it now regardless of what happens in the future.

DISCUSSION

Mortimer Silverman*: Mr. Daniels made the statement that New England could not afford to burn anything but the higher grades of coal. This is a statement with which I cannot agree. I believe that New England can afford to burn any coal which she can secure at a proper price, regardless of what its grade may be, bearing in mind the installation in connection with which it is intended to use the fuel. In other words, it is the available B. t. u. per dollar or the cost of producing steam per pound, along with consideration of the furnace capacity. Where boilers are not pushed to excessive ratings, and where grate area and furnace volumes are sufficiently large, there is no reason why the lower grades of fuel cannot be burned. The question of high freight rates is purely secondary, as we must consider the cost of the fuel delivered, and in the end, the cost of producing steam per pound.

Mr. Daniels: Of course the ultimate thing that will determine whether we use a certain grade of fuel or not is the pocketbook. The engineering of it does not amount to anything; it is whether or not it pays. That is the ultimate criterion as to whether a certain fuel can or cannot be used. You have got to consider the facts balanced up on a dollars and cents standard. That being the case, as a general proposition I think that it can be said that it does not pay to bring in low-grade fuel and pay the high freight rates that we have to pay in New England.

Professor J. T. Ward†: I wish to raise two points in connection with Mr. Daniels' extremely interesting and pertinent paper. First, I believe the statement was made that our supply of petroleum and fuel oil would be exhausted in possibly fifteen or eighteen years. May I point out that there is very competent evidence to the effect that this estimate is inaccurate. The American Petroleum Institute, probably the source of the most reliable data on the petroleum industry, has recently published a report in which are compared the estimated petroleum reserves and the cumulative production. If taken literally these data would indi-

*Assistant to Chairman, Executive Committee, Boston and Maine Railroad, Boston, Mass.

†Gas and Fuel Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

cate that we had in prospect only eight to ten years' supply of petroleum. The facts are, however, that whereas the production and consumption figures are based upon measured quantities of oil, the data showing reserves are estimates. The history of the petroleum industry shows that the figure for estimated reserves has constantly been increased. This is due to three reasons: first, every time a real shortage of crude petroleum has occurred, prospecting has been stimulated and new fields have been brought in, thus increasing both the production and estimated reserve figures. Second, the efficacy of geological means of finding oil is increasing steadily, and methods of bringing to the surface a greater percentage of the oil found are being improved constantly. Third, it has been estimated that until recently, ordinary methods of producing oil have resulted in only 25 per cent of the total oil found being removed from the ground. The new methods of water flooding, vacuum extraction, etc., are resulting in less petroleum being left in the sand.

These factors have all combined to cause periodic increases in the estimated petroleum reserves. Briefly, my first point is that experience shows that, despite the pessimistic forecast of our petroleum supply which one may gain from published statements and statistics, our means of finding and producing oil are constantly improving, and we may not anticipate an immediate acute shortage of petroleum or fuel oil.

Mr. Daniels put on slides which showed an enormous reserve of bituminous coal compared to the total coal mined thus far. I believe the slide showed that only one per cent of our bituminous coal has been mined. May I point out that while I believe this ratio to be correct, it is a fact that at the present rate of consumption the supplies of the best steam coals will be very seriously depleted during the next twenty years. If Mr. Daniels had compared the ratio of unmined reserves to the total quantity produced of, say, Pocahontas and New River coals, the ratio would be far different from the one shown. Therefore within the life of the present generation this country will be forced to the use of tremendous quantities of low-grade fuels. This is one of the primary reasons why we must look to the engineers who are developing combustion equipment, for the radical and necessary changes in our present methods of fuel utilization.

In connection with these comments it would be unfair not to state my appreciation of the particularly clear and complete presentation of this subject which Mr. Daniels gave.

Mr. Daniels: Of course as regards the amount of oil which is left in the ground available, if you say twelve years or twenty-five years it does not vary the principle that I was trying to bring home. Twenty-five years is close enough so that it will be within most of our lifetimes, and the point is that the supply that is left is not so very large.

Now, on the coal situation, the bituminous coal that was figured there includes all kinds and grades of coal in the country. As far as Pocahontas coal is concerned, real Pocahontas coal is almost extinct, and New River is perhaps fast becoming an extinct animal. The finer grades of semi-bituminous coals are undoubtedly reaching the point of exhaustion.

Supply and Utilization of Fuel Oil

By Ernest H. Peabody

President, Peabody Engineering Corporation, New York

It is my understanding that the purpose of this meeting is to discuss the conditions which govern the supply and utilization of fuels, particularly as they apply to the New England States. As will appear from what follows in this paper, the oil companies are rather preoccupied with the matter of producing sufficient gasoline to meet the increasing demands of the gasoline motor. They are less interested in the subject of fuel oil, which they must market at a lower price, and this doubtless explains the somewhat apathetic attitude of the oil companies, furnishing New England with oil fuel, toward inquiries concerning the probable supply of this fuel in your territory.

I shall therefore discuss the subject of "Supply and Utilization of Fuel Oil" as it applies to the country at large, and I may say that I find the prospect quite encouraging. I think you will have an adequate supply of fuel oil for many years to come.

A study of the conditions which at the present time govern the supply of fuel oil is of extraordinary interest and presents some very surprising factors. It is no longer the case that a quantity of crude petroleum will only produce various more or less definite quantities of gasoline, kerosene, gas, oil, lubricant, etc. The cracking process has upset these so-called natural divisions. After the fractional distillation of oil has been completed the various grades of oil may again be specially treated and partially converted into gasoline.

The more enthusiastic of the enthusiasts claim that any kind of oil can be cracked and converted into nothing but coke, gas, and gasoline. From what I hear about the troubles produced by coke in the cracking process, this claim may be perhaps almost as ambitious as the project certain chemists have set for themselves in attempting to convert bituminous coal entirely into oil. Nevertheless, a goodly quantity of liquid fuel can be made from coal, and so also the cracking process has enabled the oil refiner to place more gasoline on the market than there was originally in the oil. But this must be done at the expense of other products—and the fuel oil supply may suffer in consequence.

The discovery of the Lucas Gusher at Spindletop in 1901 marked the beginning of a new epoch in the history of fuel oil. The refineries didn't want this oil and so it went in great quantity to the fuel market. Incidentally a vast amount was wasted by the use of crude methods of burning—the hall-mark of cheap fuel—and economic losses were great. It did rejuvenate the oil-burning art, as it attracted the special attention of many engineers, and rapid strides were made in methods for improving furnace and burner efficiency.

That same oil today would doubtless in part be cracked into gasoline with a consequent loss to the fuel market. So that we are virtually facing a new epoch in the supply and utilization of fuel oil and one in which only the fittest and most efficient types of oil-burning equipment will survive.

Apparently the conditions for fuel-oil supply are not favorable. The refiners can take the heavy fuel oil we use for steam purposes and turn it into gasoline—or they can leave the heavy

oil (and doubtless will) and crack the lighter distillates, so that the drought may settle among the householders using kerosene for heating.

Apparently the situation is difficult, but there are two things—or perhaps two phases of the same thing—that will, I believe, perpetuate the extensive use of fuel oil for many years to come. The first is the keen business sense of the refiner which leads him to market as lower-priced fuel what he cannot profitably store, or sell as higher-priced gasoline. The second is that if oil is in the ground, and is scarce enough to bring a good price, somebody is going to get it. If the oil man doesn't, the wild-catter will. And so the "selling price," batted about between supply and demand, will determine the amount of fuel oil we shall have available.

I doubt if the motor car and truck and tractor, or the flying machine will ever take it all. And here, indeed, is another element to be considered as affecting the supply of fuel, namely, improvements in efficiency in the notoriously wasteful gasoline motor, thus reducing the demand for "gas." Besides this, it is possible to operate internal combustion engines with substitutes for gasoline not derived from petroleum. Perhaps the American public will never insist on the saving of gasoline until the price goes up materially, and then the demand will go down and the price with it—meantime we will have more oil to burn for steam-power purposes.

I need not discuss at length the probable reserves of crude oil. There appears to be enough to last quite a while. The oil recoverable in the known fields by present methods of flowing and pumping was estimated in 1922 as nine thousand one hundred and fifty million, or over nine billion barrels. This was the figure set by the United States Geological Survey and a special Committee of the American Association of Petroleum Geologists.

The "Committee of Eleven" of the American Petroleum Institute, in their absorbingly interesting report published recently, calls it five thousand three hundred million barrels, with twenty-six thousand million barrels left in the ground, and at least partially recoverable by improved methods. I have good reason for believing that these figures are on the "bear" side, and it will be noted that it considers only the proven oil fields. There may be and probably are other fields not yet explored.

Estimates of the world's reserves, obtained by shrewdly guessing at a quarter and multiplying by four, are upwards of forty and fifty thousand million barrels. None of these estimates includes the vast deposits of oil shale nor the oil obtainable from coal.

Major Geo. M. Talbot, under whose direction all fuel purchases are made for the United States Fleet Corporation, writes me as follows under date of October 23, 1925:

"One of my principal functions during the past six years has been to study production and consumption of crude petroleum and its by-products throughout the world, and especially in the United States. After watching development of various producing fields year after year, I am of the firm opinion that there is no justifiable reason for the belief by some that the source of supply of crude petroleum in the United States will become exhausted in the near future. Although consumption of by-products of petroleum has been rapidly increasing, the yearly increase in production during the past five and a half years has more than kept pace with the increase in consumption. The present rate of production indicates that there will be at least as much oil produced during the last six months as was produced during the first six months of 1925, which would make the total production for the year nearly 750,000,000 barrels. It is estimated that the consumption plus exports of crude petroleum in the United States for 1925 will be around 725,000,000 barrels. This shows that production in 1925 will be substantially in excess of consumption."

In substantiation of Major Talbot's estimate I may, through the courtesy of the Petroleum Institute, state that the production of crude oil in the United States for 1925, up to and including November 28, equals 692,775,000 barrels. A good many people in authority have been inclined to consider 1923,

with over 732,000,000, as marking the probable peak of United States production. It doesn't look like it now.

Now, as to fuel oil: In 1915 I had occasion to ask the late Dr. David T. Day (then of the United States Bureau of Mines) what proportion of the total crude oil production might be considered as fuel oil. His estimate was 40 per cent. It has far exceeded this in recent years, the average for the five years, 1920 to 1924, inclusive, being more than 53 per cent.

The following table of crude production and fuel oil supply for this period will be of interest:

steam atomizers used in locomotive service consumed at least 7 per cent of the fuel for generating the steam merely for atomizing the oil. And yet it seems that no interest whatever can be aroused in railroad circles in carrying out experiments with the type of burner which has been so successful under highly forced rates of combustion in the United States Navy. These burners are more economical than steam atomizers, and use no steam whatever for atomizing. They should, therefore, at the very least, save all the 7 per cent. This is rather a disheartening condition when it is considered that the railroads in this country in 1924 used 63,000,000 barrels of precious fuel oil.

U. S. CRUDE OIL PRODUCTION AND FUEL OIL SUPPLY

IN BARRELS OF 42 GALLONS

Year	1920	1921	1922	1923	1924
Crude petroleum produced in the U. S.	442,929,000	472,183,000	557,531,000	732,407,000	713,940,000
Crude petroleum imported into U. S.	106,175,000	125,364,000	130,255,000	82,015,000	77,775,000
Total produced and imported	549,104,000	597,547,000	687,786,000	814,422,000	791,715,000
Crude petroleum and fuel oil exported	8,583,000	9,552,000	10,637,000	17,210,000	17,784,000
Total available for consumption in U. S. and for export of refined products	540,521,000	587,995,000	677,149,000	797,212,000	773,931,000
Total consumed for fuel	296,551,000	296,946,000	347,002,000	430,107,000	429,701,000
% of U. S. supply of crude used for fuel	54.86	50.50	51.24	53.95	55.52

Authorities: United States Geological Survey, United States Bureau of Mines, United States Bureau of Foreign and Domestic Commerce, and American Petroleum Institute.

These are encouraging data for those interested in the use of oil fuel. Just what the oil drill, the cracking process, the gasoline engine, the efficiency engineer, and the dollar will bring forth in the future, is decidedly a matter of speculation. But there seems to be little cause for apprehension just at present.

However, the certainty that there is a limit somewhere ought to stimulate our interest in, if not our efforts for, improved methods of utilizing fuel oil. There are glaring instances of needless waste. A prominent railroad official, noted for his careful observation of combustion conditions and test results, informed me two years ago that the

I now wish to discuss a very recent development which is closely allied with the subject of oil fuel, namely, the use of powdered coal as fuel in furnaces originally designed for oil burning.

Oil for steam purposes must compete with coal on a price basis. But these prices fluctuate and vary with respect to each other. When the price of oil is within any sort of range of that of coal, oil is the preferred fuel for many reasons.

A demand seems, therefore, to exist for a burner and furnace equipment that

will, with little or no change or alteration, handle either coal or oil. Coal in the powdered form lends itself to such an idea.

Just what, if any, modification in furnace design may be required has not yet been fully worked out, but the burner has been developed suitable for both fuels, and incidentally the application to the combustion of powdered coal of principles which have long been successfully used with oil has resulted in a surprisingly short, clear flame and indicates a probable very considerable reduction in the furnace volumes required.

This burner is the development of the Peabody Engineering Corporation and is now being tested in connection with unit pulverizers by the New York Edison Company, at the Sherman Creek Plant of the United Electric Light and Power Company, New York. No official results of these tests are yet available, but I may say that the figures are extremely gratifying and indicate a real advance in the art.

One of the circumstances that encourages the belief that a combination coal and oil burner is desirable is the recent change from oil to coal fuel in the boiler plant of the American Sugar Refining Company in South Boston. I think the following letter which we received from Mr. F. M. Gibson, plant engineer of that company, may be of interest in this connection, both for its engineering and economic aspects:

"In reply to your recent letter asking the reason for changing from oil to coal in our Boiler House, let me assure you that it was due solely to the comparative purchase prices of oil and coal.

"Contrary to general impression, the contract proposals for fuel oil for 1925 quoted prices lower than the price paid in 1924. This reduction was more than offset by the decided reduction in the price of coal.

"With a highly successful oil installation, such as we had, with its high efficiencies, ease of control, ability to closely follow a rapidly fluctuating steam demand, ease in placing a boiler on or off the line, low repair costs, accuracy in measuring fuel and cleanliness, it is difficult to understand why any operating engineer would wish to change to coal burning for any other reason than the price of fuel.

"Pulverized fuel systems were considered, but, for reasons of high initial cost and structural alterations required for large furnace volumes, it was found advisable to install underfeed stokers.

"The installation of stokers has proven satisfactory in every way, and the reduction in steam costs shows that the change was justified.

"If there is any further information on this subject which you may desire, please do not hesitate to call upon us."

Mr. Peabody then showed a number of interesting illustrations of early and later improved methods of utilizing fuel oil, and discussed the various conditions conducive to improved efficiency in the use of oil.

Typical oil-burning plants were illustrated, including the original installation of Peabody-Fisher wide-range mechanical atomizers at the American Sugar Refining Company, Boston.

In conclusion, the Peabody Combined Pulverized Coal and Oil Burners, installed at the Sherman Creek Plant of the United Electric Light & Power Company, New York, were illustrated and described.

Diesel Engines for New England Power Plants

By J. F. Hecking

Worthington Pump and Machinery Corporation, Cambridge, Mass.

In determining the proper prime mover for installation in a central station or an industrial plant it is generally found that factors other than the efficiency of the units are of primary importance. If this were not true we would find that practically all our industries of moderate capacities would be equipped with internal combustion engines operating on the Diesel cycle, since this is the most efficient prime mover produced commercially.

The limiting factors are suitability or cost, or both. For fuel-burning stations the proximity of low-cost fuel, the load factor, and quite a number of other items are of importance in determining suitability. Nearly all of these considerations also apply to hydro-electric developments, which, however, have several additional items, the most important being development cost and location of demand.

When we consider the remarkable over-all efficiencies that are being reported from forty, fifty, and sixty thousand kilowatt turbo-generators; performances running up to 15,000 B. t. u. per kilowatt on the switchboard when operating on reheating cycles, we are inclined to wonder to what extent the improvement can be carried on. But here we encounter a limitation. Of what use are these efficiencies when units of 30,000 kw. or more are required to develop them and when there are not fifteen central stations throughout New England having an installed capacity of 30,000 kw.?

Diesel Engines for Central Stations

A recent survey of the fuel-burning central station capacity east of New York gives a total of 2,050,000 kw. Of the total number of stations, over 65 per cent are of less than 7500 kw. capacity.

It is in these smaller stations, which are usually located close to a demand, that the Diesel engines may be installed to advantage. Taking care of such remote demands from the larger central stations is always limited by the line cost and transmission losses which quickly nullify the economies of the larger station.

As you are all familiar with steam-plant costs, we will examine in detail the case for the Diesel plant of 7600 kw. The station would be made up of four 1900 kw. units giving a peak capacity of 5700 kw. with one unit as a spare at all times. The building required would be approximately 80 ft. square. For such a station the installation and power costs are as follows:

Real estate	$ 6,000
Building	75,000
Siding	3,000
Oil tanks	20,000
Water storage	5,000
Water and oil piping	5,000
Engines	680,000
Generators	80,000
Switchboards	30,000
Motor wiring	5,000
Light wiring	3,000
Outdoor dist. structure	8,000
Auxiliary compressors	2,000
Equipment foundations	18,000
Water intake	7,000
Water supply pumps	3,000
Exhaust piping	5,000
Intake air filters	2,000
Crane	7,000

Machine shop equipment	$6,000
Contingencies	30,000
Total	$1,000,000

Summary

Real estate, building and r. r. siding	$ 100,000
Generating units, complete with switchboard and wiring	850,000
Piping, pumps, and storage	50,000
Total	$1,000,000

The cost for the complete installation would be about $132 per kilowatt installed. On a peak capacity figured with one unit off, the cost would be $175 per kilowatt-hour.

The costs of operating the above plant for various loads are as follows:

These figures compare quite favorably with those of fuel-burning central stations of much larger capacity.

The matter of water-power development is being given considerable attention throughout New England. The idea that water power costs almost nothing seems to be quite popular and is based on the excellent performance of certain stations now operating. We, of course, do not lose sight of the fact that economic and geographic factors have made quite a number of the larger water-power developments successful. These developments have been on the more favorable sites where the development costs have been low or where the load was near by.

Comparisons are frequently made with water-power developments out West. Such comparisons are usually on

		Cost per Kilowatt-hour
25% Load Factor		
Fuel @ 6c per gallon	$ 80,000	
Labor—6 men	15,500	
Lubricants	2,500	
Miscellaneous supplies	3,000	
Production charges	$101,000	8.1 mills
Fixed charges @ 13%	130,000	10.4 mills
Total	$231,000	18.5 mills
50% Load Factor		
Fuel	$140,000	
Labor—7 men	17,000	
Lubricants	3,600	
Miscellaneous supplies	3,400	
Production charges	$164,000	6.6 mills
Fixed charges @ 14%	140,000	5.6 mills
Total	$304,000	12.2 mills
75% Load Factor		
Fuel	$202,000	
Labor—8 men	19,500	
Lubricants	4,200	
Miscellaneous supplies	3,800	
Production charges	$229,500	6.1 mills
Fixed charges @ 15%	150,000	4.0 mills
Total	$379,500	10.1 mills

a head, flow, and storage basis, and no mention is made of relative land values, flooding damages, and highway relocation. These factors may cause a New England development to cost over 50 per cent more.

According to the best information available, the water-power sites in New England amount to about 570,000 kw. based on 60 per cent availability. Of this total about 45 per cent can be obtained at a cost of $150 per kilowatt or less; the remainder will cost up to $600 per kilowatt installed.

These figures cover the items of land and water rights, reconstructed roadways, and power-plant structures; they do not include the stand-by equipment, which will bring the cost of the complete plants in the first group mentioned to about $300 per kilowatt, while the second group would run up to $800 per kilowatt based on the kilowatt capacity of the water turbines.

As the cost of the water-power development increases it becomes necessary to devote more attention to the efficiency of the stand-by equipment. The present practice of using steam engines or turbines frequently burdens these stations with charges which on the low average amount to about 15 per cent of the power costs. It is safe to assume that this can be brought down to much less than 8 per cent through a proper application of Diesel engines.

This assumption may seem very broad, but it must be remembered that first, the Diesel engine is very efficient; second, the efficiency is almost independent of the load within the usual commercial variations; third, the size of the units has little effect on the efficiency; and last, there is no radical difference in cost between a Diesel plant and a good steam plant.

Because of the second and third items it is possible to operate a small unit of five or six hundred horsepower in parallel with the water wheels during the beginning of a low water period and taking the load on a second or a larger unit as the water shortage increases. Coupled with this flexibility there is the complete absence of stand-by fuel consumption; in short, the combination is ideal. The combination has been applied to a number of the smaller stations in New England, and in each instance has proved successful.

We have considered the application of Diesel engines to central stations. As to whether they can be applied to industrial plants will now be considered.

Diesel Engines for Industrial Plants

In industrial plants the decision as to suitability of a source of power is based principally on the size and character of the load, the relative fuel cost, and the necessity of producing heat. Throughout New England the last item is of utmost importance; first, because heating of plants is necessary from six to eight months of the year, and second, because a few of the principal industries require hot water for process work.

The majority of the industries in New England have a very satisfactory type of power load; it starts at a definite time and continues at an almost uniform rate throughout the day. In several industries, it continues almost uniform for over 125 consecutive hours. On loads of this type the central stations can and do make very reasonable rates—rates which are practically at cost.

When this type of load for some economical reason is much removed from the central station, transmission costs begin to build up the rates so that purchased power, although very reasonable in view of the circumstances, becomes expensive. For such stations Diesel engines are advantageous.

Let us take for example a plant with an average demand of 500 kw. for 48 hours per week. Usual industrial practice sanctions the installation of just enough capacity to take care of the maximum demand without stand-by units, and in our example we will install 600 kw.

The power plant will be made up of two 300 kw. units in a building 40 ft. square. The installation and power costs are as follows:

Real estate	$ 2,000
Building	10,000
Siding	1,500
Oil tanks	1,000
Water storage	2,000
Water and oil piping	2,000
Engines	68,500
Generators	8,000
Switchboards	2,500
Wiring	1,500
Auxiliary compressors	900
Equipment foundations	3,500
Exhaust piping	1,500
Contingencies	3,000
Total	$107,900

Summary

Real estate, building, and r. r. siding	$ 13,500
Generating units, complete with switchboard and wiring	87,000
Pump, piping, and storage	7,400
Total	$107,900

The cost would be about $179 per kilowatt installed.

Industrial plants do not obtain the higher load factors which are always desirable. We have assumed for our example a load factor of 25 per cent and the cost will be as follows:

Fuel	$ 8,450
Labor	3,000
Lubricants	300
Supplies	200
Production charges	$11,950
Fixed charges @ 13%	14,000
Total	$25,950

For this plant the production charges would be 9.1 mills per kilowatt-hour, and 10.6 mills for the fixed charges—a total of 19.7 mills per kilowatt-hour.

The above figures compare favorably with the purchased power rates; in fact, most manufacturers with such a demand are paying more than this for their power. As compared with the costs of those plants producing their own power, and which need quantities of steam for heating, there may be some division of opinion.

There is an idea quite prevalent among operating engineers that power costs nothing when generated from steam subsequently used for heating. If it were possible to strike a balance whereby the power consumption would vary as the weather, there would be some basis for this assumption. In the majority of New England's industries the power demand is fairly constant, and the demand for heat in the form of steam is only during six or seven months of the year, and then in variable quantities.

If the power demand is sufficiently large it is possible to produce a very efficient bleeding system, but on the average the system becomes rather expensive. With such systems the power bill becomes negligible during the colder periods of the winter, but with the average steam equipment about 75 per cent of the entire annual fuel bill is chargeable against power.

Several plants are using Diesel engines in conjunction with inexpensive steam equipment to satisfy both power and heat requirements. The steam engine carries the load to the extent of the steam requirement, and the Diesels provide all the power and hot water for process work and service outlets during the part of the year when heating is not necessary.

The large stations which have been built in New England are equipped with turbo-generators because this type of prime mover has been considered most suitable. One of the objections to Diesel engines in these larger stations has been the necessity of using six or eight engines to accomplish the work of one or two turbines. At present engines up to 9000 hp. are in marine

service, and there are now a number of stations of more than 10,000 hp. operating. With the development in this country of engines over 1200 hp. per cylinder there are available engines of larger sizes, two or three of which would satisfy most power demands.

Summary

Diesel engines for moderate-sized stations are receiving more and more attention by power-plant designers. These engineers, after giving all the factors full consideration, find that the Diesels fill the demand for efficiency and economy.

The small installations are those in which Diesel engines nearly always work out advantageously. Because of the inefficiency of small steam equipment, the cost of fuel in small quantities, or because of the cost of power in small quantities, the Diesel engines are being installed in increasing numbers. Based on the best information available the sales of Diesel engines in sizes under 500 hp. have amounted to over a third of a million horsepower during the past year. This figure will gradually increase as the advantages are more universally realized.

Possibilities of Obtaining Industrial Power from Public Service Corporations

By L. R. Nash

Vice-President, Operating Division, Stone & Webster, Inc., Boston, Mass.

It is my purpose, in discussing the subject of the supply of utility power to industries, to deal with only the broad, general principles which enter into comparative costs. Illustrations might be given of specific propositions, but the typical character of any selected illustration might in some respects be open to question. It will, therefore, better serve our purpose and avoid confusion to deal only with fundamental considerations.

The supply of utility power to industries has developed almost wholly within the last twenty-five years. In fact, twenty years ago only 3 per cent of the total power requirements of manufacturing industries was purchased from public utilities. This percentage has increased steadily in the intervening years and rapidly within recent years. In 1922, 37 per cent of all industrial power in the United States was furnished by public utilities as compared with 24 per cent (less than two-thirds of the purchased quantity) generated electrically by the industries themselves. The balance, 39 per cent, was produced and distributed mechanically from steam or water-power plants owned by the industries.

The amount of the mechanical class of power has decreased both in quantity and proportion. The quantity of electrical power generated by the industries has steadily increased, but the percentage has remained fairly stable until recent years, during which it has diminished.

Electric power plants owned by manufacturing industries in the United States have an aggregate capacity of something over 6,000,000 kw. Of this total 30 per cent is in the iron and steel industry, which requires process steam, has by-product fuel, or for other reasons can produce power at low net costs. The chemical industry has about 15 per cent of the total and also requires large quantities of process steam. Textiles, coal mining, and paper and printing come next in order with plant capacities ranging from 11 per cent down to 3 per cent of the aggregate. Other industries have less opportunities of reducing their cost of power through by-products or steam requirements. In all important groups except iron and steel, first mentioned, the amount of electric power purchased is greater than that generated, but not greater than the total power generated by the industries, including mechanical means.

The industrial power situation in Massachusetts is not essentially different from that in the country as a whole. Our industries have a total reported available power capacity of about 1,800,000 hp. to take care of an actual load of 1,250,000 hp. This apparent reserve capacity is not typical of the isolated plants, and probably includes motor-rated capacities or purchased power availability in excess of actual loads. One-sixth of the total capacity is in industries requiring process steam. The total annual power requirements of Massachusetts industries are equivalent to about 7,500,000,000 kw.h., of which 30 per cent is produced by water power. Approximately one-half the total

power requirements are furnished by the industries themselves and one-half is utility power, the proportion of the latter being, therefore, appreciably greater than for the United States as a whole.

It is now in order to consider the reasons for the progressive increase in the use of utility power in manufacturing industries. Power costs are commonly divided into two groups, covering investment charges and operating costs, respectively, and these groups will now be considered.

With the passage of time, increases have occurred in the sizes of both industrial and utility plants. The increase in the latter has, however, far exceeded that of the former. In 1907 public utility power plants which had capacities of 5000 kw. or less contained 30 per cent of the total capacity of such stations. In 1923 such stations included only 15 per cent of the total capacity, a reduction of 50 per cent. In 1923 public utilities had more than eighty stations with a capacity of 50,000 kw. or more. Practically all the growth in public utility plants during the last twenty years has been in those with capacity exceeding 5000 kw. Many small plants have become non-operative because of their absorption in interconnected systems. At the present time 60 per cent of the total utility generating capacity is in modern turbine units.

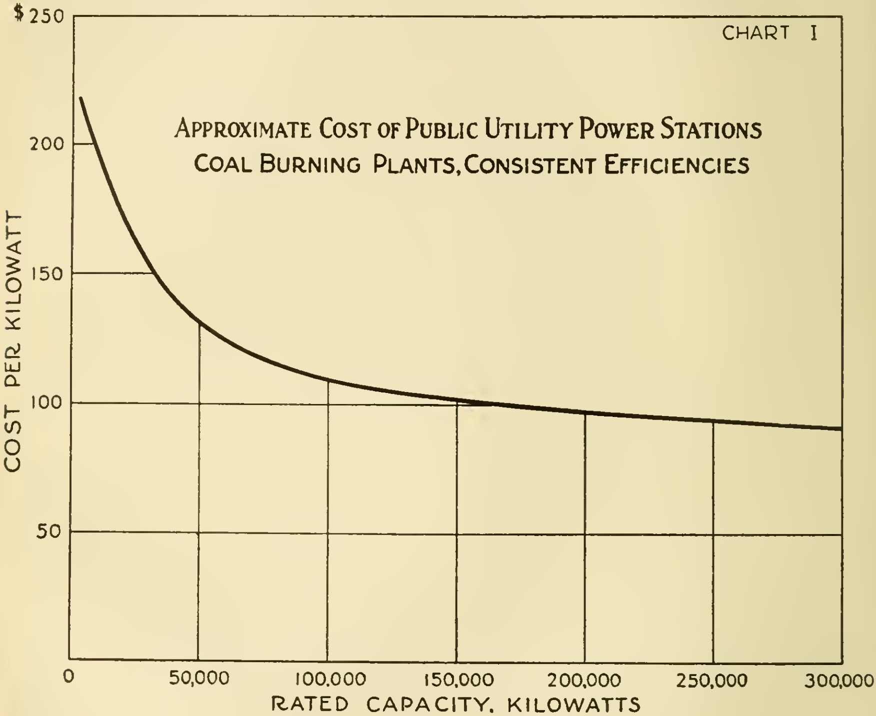

FIG. 1

It is obvious that a large power plant costs less per unit of capacity than a small one. An efficient coal-burning station of large capacity (by which I mean 150,000 kw. or more) can be built at a cost of about $100 per kilowatt. The unit cost does not decrease materially for larger plants, but, on the other hand, an increase is distinctly noticeable in smaller plants. For capacities of 30,000 kw. the cost will be about $150 per kilowatt; for 10,000

kw., not less than $200; and with still higher costs for smaller plants. These costs, shown in Fig. 1, are intended to be generally representative of well-designed stations with consistent attention to efficiencies in all cases. Many small stations are built at lower costs than those indicated, but without the assumed efficiency and, therefore, involving a higher over-all cost of power.

We have, therefore, at the outset a distinct advantage for public utilities in the lower unit cost and carrying charges of their power stations. This is offset only in part by the cost of the transmission and distribution lines and customers' sub-stations which the utilities must provide to deliver power to industries. For large customers this supplementary cost will run from $10 to $20 per kilowatt, depending upon the extent to which transformation is necessary and the distance of the customer from the supplying station. Where long-distance transmission is involved in such power supply it is assumed that the cost of such transmission is offset by the lower cost of hydro-electric power or generation in interconnected systems or super-power tidewater stations.

Large utility plants also have an advantage in a diminishing percentage of relay capacity required to insure continuous service. A study of existing plants throughout the country shows that the smaller ones (10,000 kw. and under) have reserve capacity of 25 to 30 per cent, whereas stations of 200,000 kw. and upwards have about 10 per cent. This latter percentage may in some measure be due to the availability of smaller relay stations. It has been pointed out that the reserve installed capacity in Massachusetts industries is about 33⅓ per cent. This may not be typical, and the lower percentage of relay capacity required in utility stations is not offered as a significant contributing factor toward lower cost of utility power. Many industries operate their own power plants without reserve capacity and secure service which may compare in reliability not unfavorably with that furnished by public utilities, at least where extensive transmission is involved.

An investment factor which is of importance lies in what is called the diversity in utility power load. This diversity arises from the intermittent character of power use and the general use of lighting service at times when power requirements are substantially reduced. To the extent that utility plants can utilize their capacity to serve two or more distinct classes of customers at different times, their unit investment for each class is reduced. An industrial plant, on the other hand, while having diversity in use among different processes, has no such advantage in this respect as is enjoyed by utility plants, and each unit of investment must, therefore, be carried by a relatively smaller output.

It is more common to refer to the extent of use of facilities by the term "load factor," the ratio of average load to maximum load for a given period, or the percentage of the time which maximum load would continue in order to give an output equal to the actual. Industrial plants have a load factor under ordinary operating conditions less than 25 per cent, continuously operated industries being, of course, an exception. A well-developed utility power system has a load factor of 40 per cent, and there are many cases of much higher load factor. Utility station load factors have increased to a significant extent with the advent of power loads. A typical Massachusetts station which has been under my observation for many years had twenty years ago an annual load factor of 20.3 per cent. It now has a load factor of 40.6 per cent, or exactly double that of twenty years ago. Although better lighting and more extensive appliance service have contributed to this improvement, the major part of it should be credited to industrial power supply, and is indicative of the extent to which utility plants can take on industrial load without proportional increase in investment.

Turning now to operating costs, we find comparisons also favorable for utility power service. The average fuel consumption in utility plants is not far from two pounds per kilowatt-hour. The largest and most modern plants use but little more than one pound of coal, or about 15,000 B.t.u. Only a few years ago the average consumption was three pounds. The improvement has come about through increase in size of stations and more intensive engineering studies of efficiency. It is interesting to note that in 1919 public utility plants generated 24,000,000,000 kw.h. with a fuel consumption of 39,000,000 tons of coal or its equivalent. Five years later the steam-generated output had increased to 30,000,000,000 kw.h. with a fuel consumption of only 38,000,000 tons, or 1,000,000 less tons than had been required five years before, although the output had increased 25 per cent.

It is difficult to secure comprehensive, reliable figures of the fuel economy of industrial plants. Many such plants fail to keep accurate cost statistics, and the compilation of all such costs is not available. Indications of the probable fuel requirements of industrial plants can, however, be obtained from an analysis of the performance of utility plants of varying sizes. Such analysis shows, for the United States as a whole, that utility plants having capacities of 50,000 kw. and upward are operating at about 20,000 B.t.u. per kilowatt-hour. Plants of capacities from 10,000 to 50,000 kw. require about 25,000 B.t.u. Plants under 10,000 kw. require from 30,000 B.t.u. upward. A considerable number of plants of 500 kw. of capacity or less show over 100,000 B.t.u. Such high consumption is usually due to poor design, low load factor, or non-condensing operation. It therefore appears safe to say that industrial plants of efficiencies equal to those just stated for their respective sizes will require two or more times the amount of coal per kilowatt-hour used by a utility plant capable of serving a large city where such industries are commonly located.

Based upon my knowledge of industrial plants, I am inclined to think that they are not usually operated with the same skilled attention and resultant efficiency as are utility plants of similar size. The constant increase in utility power supply has meant repeated additions to generating capacity of larger and more modern units and an increasing attention to engineering refinements, with the result that modern utility stations of certain capacities are much more efficient than stations of similar capacities installed in earlier years. Industrial power plants do not have the same opportunities for improvements in economy.

Among the remaining operating costs labor is the most important item. Obviously the labor cost per unit of output in a large plant is much less than such costs in a smaller plant. This statement is confirmed by abundant statistics and does not need amplification. Utility plants have an advantage here that is not ordinarily offset by the use in industrial power plants of labor that is otherwise partially employed.

It is also obvious that the incidental expenses of operation and maintenance costs are less in large stations than in small ones. Many utility plants have the further advantage that their maintenance is taken care of through carefully prepared schedules under which every important piece of equipment is periodically examined and adjusted, thereby keeping operating efficiency at the highest point and avoiding breakdowns and service interruptions.

Utility plants can also be located more favorably with respect to condensing water supply and fuel than can industrial plants. The production of power is only an incident in manufacturing processes, labor and other factors being much more important; and the convenience of access to employees is an important consideration which does

not apply in the case of utility power plants. All the above factors are favorable to low comparative utility power operating cost.

Of the two classes of power costs discussed, it appears that utility plants are apt to have greater advantage in operating cost than in carrying charges. The latter may even be greater than those of industrial stations which have been built without similar regard for operating economy. Many industrial plant managers recognize that the operating cost of their own power plants, while originally comparable with utility plant costs, has not kept pace with utility plant development and that, if they did not have a large existing investment in power facilities, it would be advisable to purchase utility power. Utility managers in increasing numbers are recognizing this situation, but are confronted with the existence of an operative industrial plant which would be idle if their service were substituted, such service ordinarily requiring not only active plant equipment but also a suitable amount of relay capacity. The problem has been to eliminate this duplication of spare capacity, and it has been solved in some cases by the supply of so-called "unrelayed" service. Such service is furnished by utility plant equipment which is normally held in reserve. When active equipment is withdrawn for repairs or emergencies, the reserve equipment must be used for regular utility service and the industrial customer is called upon to operate his own plant for a limited period. Such service involves lower cost to the utility because of the reduced investment required, and may be attractive to industrial customers if absolute continuity of service is not required, and the probability of curtailments of the utility supply or the duration of such curtailments does not involve excessive standby or operating costs of the reserve industrial plant.

No further discussion of rate structures is appropriate in this paper other than the statement that the demand form of rate, commonly used by the power companies for wholesale service, has obvious advantages to both company and purchaser, and permits a maximum development of business.

It has been well said that the proof of the pudding is in the eating. A report prepared in 1924 by a committee of eminent engineers on the "Power Requirements and Sources of Supply in New England" contains some interesting data comparing the cost of power generated in New England industrial plants with the rates for electric power quoted by utility companies. The figures given in the report and summarized in Fig. 2 show normal maximum and minimum utility rates covering the usual range of industrial requirements, and the cost of power produced in similar quantities in industrial plants without process steam requirements, and under the assumption that the entire exhaust from these power plants could be utilized for such requirements. It appears from these data that the cost of industrial plant power up to nearly 10,000 hp. capacity, without process steam requirements, is in excess of the normal maximum rates for utility service, and that when all steam can be used for process purposes, the cost of industrial supply is also greater than the minimum rates charged for utility service for plants under about 7000 hp. capacity. Very few plants make such extended use of process steam, and the conclusion is, therefore, justified from the report referred to, that the rates for utility power, in blocks not exceeding 10,000 hp., are normally below the cost of producing this power by the industries. Where larger blocks of power are involved the larger and more efficient utility plants would still show a material advantage although the smaller ones might not.

The estimates of industrial power costs, included in the power report just referred to, presumably include many items of cost which are frequently

omitted from estimates of such costs made for comparison with utility power. Among the items so omitted are administration and other pro-ratable service, carrying charges on fuel and other supplies, rental value of space occupied, liability and other insurance, taxes, adequate allowances for depreciation and obsolescence, and a fair return (as distinct from a bare interest rate) upon the invested capital. In the many estimates which I have examined of industrial power cost prepared by industrial plant officials or engineers, I have rarely seen one which made suitable provision for all these items. Many also make inadequate provision for fuel through lack of accurate records or other knowledge of operating economies or through use of manufacturers' statements of possible efficiencies not usually maintained in practice.

This discussion has not considered in detail the use of process steam and by-products of the industry in connection with power production. In many cases such as the steel industry, previously referred to, the advantages of these factors are such that utility power cannot advantageously be used. Each such case should be the subject of special study and decided upon its own merits. The textile plants, at least the cotton mills, so numerous in New England, do not ordinarily come within this group of doubtful cases. Their requirements for steam heating do not ordinarily exceed 15 per cent of their maximum power requirements, and the peak of the steam-heating load comes during early morning hours, ahead of the industrial load, the average heating load during production hours being substantially less than the maximum. Their process-steam requirements vary through wide limits, and may be controlling in some cases.

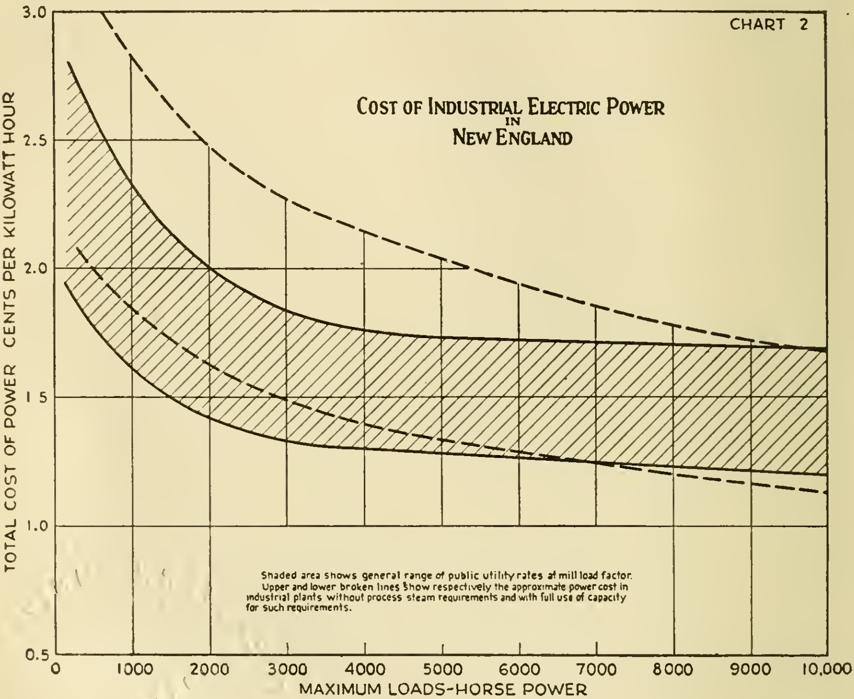

FIG. 2

New England utilities have not been

subject to keen competition from one means of power production actively exploited in other parts of the country. The Diesel engine is in extended use in small plants in the south and west where fuel oil is cheap as compared with suitable grades of coal. The Diesel engine is an efficient unit for plants of moderate capacity. It has a fuel consumption of about 15,000 B.t.u. per kilowatt-hour for fairly large units, but this efficiency does not improve as the size of stations increases because the number of cylinders rather than their size is increased to make up the total capacity. The high investment and high upkeep cost bring about a higher overall cost of power in large stations than from turbine units, unless the fuel-oil cost is exceptionally low or the load factor exceptionally high.

The rapid growth of utility power plants, their interconnection over large areas, the advantages of reduced relay capacity, and the continuous operation of the most efficient units of the system all point to further reduction in the cost of utility power and its more favorable comparison with independent industrial plants. Our power development in this country has reached limits far exceeding those of any other country. With only 7 per cent of the world's population, we have one-half of the world's use of electric power. Our industrial workers have seven times as much power at their elbow as those of other countries of the world, amounting for each worker to the equivalent of about forty men. It is this factor which has contributed very largely to our national prosperity and the comforts and advantages enjoyed by our industrial workers.

In closing I would suggest that undue emphasis has frequently been placed upon the cost of power in industry. On an average such cost amounts to less than 3 per cent of the value of industrial products. Industries should be located and managed with primary attention to the more important elements of cost, such as labor and raw material. None of these important factors should be sacrificed in the interests of power economy which can affect the final cost of the product by only a fraction of 1 per cent. The permissible reduction of investment when power is purchased and the curtailment of fuel and administration problems are also pertinent factors. Utility power is increasingly dependable and has increasing advantages which should not be overlooked in a study of alternative costs, particularly when such costs, as stated, usually differ by only a negligible percentage of the value of manufactured products.

DISCUSSION

Dr. Samuel W. Stratton*: I have been particularly interested in this paper, just having gone through the problem of having to decide whether we would utilize the Public Utility current or extend our own plant, and there were a great many facts given in this paper which we would like to have had some few months ago. However, our condition is not quite the same, since we have a good plant, and an increase in its capacity would mean little increased cost in operation.

I was particularly interested in hearing Mr. Nash say that the time has come when industry can be located with reference to raw material and other things, that fuel is not the determining factor.

Question: I would like to inquire what percentage of electric power produced it is possible to deliver at present

*President, Massachusetts Institute of Technology, Cambridge, Mass.

by long-distance transmission—say 100 miles. Supposing a factory is 100 miles from the source of power, about how much power would actually be received? What would be the loss in transmission?

Mr. Nash: Transmission lines are usually designed for losses of about 10 per cent, and that is to a considerable extent independent of the distance of transmission.

Question: I am particularly interested in the figure of capacity value of steam plants, and in particular Mr. Nash's figure of $100 per kilowatt-hour. I would like to ask the B. t. u. rating of his $100 plant.

Mr. Nash: Something in excess of 15,000 probably, but not very much for a large plant. A small plant with that low unit cost would have a much lower efficiency and correspondingly higher B. t. u. rating.

Power for Textile Mills

By Charles T. Main

Engineer, Boston, Mass.

Most of the earlier textile mills were located upon a river, in order to take advantage of water power. Many of the manufacturing centers were started in this way, and the sites of many of the isolated mills were chosen for this reason. Many of the water powers which have been so used have been outgrown, and in some of these places there is a preponderance of steam power over water power. New centers of manufacturing have grown up, where cheap fuel and low rates for transportation can be obtained, and many mills are driven by steam power.

More recently the transmission of electrical current and the use of electrical power in the mills have caused water powers which were remote and of no value to become useful and valuable, and have enabled the construction of central power stations near the mines or on tide water where cheaper fuel can be obtained. These recent developments have made it possible to locate the mills more advantageously with reference to labor centers and with reference to the physical structures, light, and railroad facilities.

The chief items of the cost of textile manufacturing are materials and labor. The cost of power is rarely over 5 per cent of the total cost of the product of the mill, and while the cost of power is an item which should receive careful consideration, it is of more importance to locate in some place where a sufficient number of operatives can be procured, and where reasonable freight rates can be made, than to locate where power is cheap and the other items lacking. The relative importance of locating where power is cheap increases as the ratio of the cost of power to the value or cost of the product increases.

Some of the earlier mills located on a variable stream, primarily for the sake of using water power, which power to a large extent requires supplementary steam power, are probably handicapped on account of their location, the restricted methods of construction, and by the necessity of maintaining and running a double power plant.

At the present time, many of these restrictions have been removed on account of the possible use of electric power produced by the company itself, or which can be purchased from some power company producing by water or steam, or a combination of both.

In many instances, the promoter of a new enterprise can have his choice of producing his own power or of purchasing electric current from a Public Service Corporation. The latter course is now largely followed by mills of moderate size, which have not a considerable use for steam or warm water in the manufacturing processes. The problem of the type of plant to be used has largely disappeared.

With the exception of some plants of small size, nearly all the power installations being made in textile mills now use electric transmission. In this paper it is, therefore, assumed that the power will be transmitted electrically.

In the earlier electrical installations it was common practice to use large motors, 100 hp. or more in size, to drive large groups of textile machines. There has been a continuous tendency to decrease the size of the group of ma-

chines driven by one motor, and to use the individual motor for each machine. It is common practice now to limit the size of motors for group drives to about 40 or 50 hp., and to use individual motors ranging in size from ½ hp. to about 10 hp. on many of the textile machines.

As regards the conditions which affect the power problem, textile mills may be divided into two general groups:

(a) Plain goods cotton mills, which require little or no steam or warm water in their manufacturing processes, and other similar mills.

(b) Woolen and worsted mills, which require large amounts of steam and warm water in their finishing processes, and so can make use of the waste heat from the generation of power, and similar mills.

There is, roughly, 1¼ million horsepower used by the cotton mills and about ⅓ of a million horsepower used in the woolen and worsted mills in this country.

Steam Power

Nearly all values and costs of power are at the present time compared with the cost of producing power with steam. All of the statements of cost which follow are based on present prices, and are subject to change from time to time with the change in any element going to make up the totals. Prior to 1913, prices and costs were fairly constant; since 1913 they have increased so that today they are, roughly, double the 1913 prices.

An industry which is not yet established can, by using steam power, locate at any place where it seems desirable; but if possible the location should so be made as to warrant a supply of water for boilers and condensers and for manufacturing purposes, if any is required.

In making up the cost of steam power, all charges have been considered, except interest and taxes on the cost of land. The fixed charges, including depreciation, interest, insurance, and taxes, have been assumed at 12.5 per cent, and the running time 50 weeks of 48 hours each, or 2400 hours a year. In determining the cost per kilowatt-hour, it has been assumed that the average load for the running time is 90 per cent of the capacity of the plant. The cost of coal is assumed at $7.00 per long ton delivered in the coal pocket, and oil at $2.00 a barrel in tankage.

The principal items affecting the cost of steam power are as follows:

1. Cost of fuel delivered to boilers.
2. Amount of power produced.
3. Fixed charges on cost of plant.
4. Repairs and maintenance.
5. Attendance and supplies.
6. The net cost is reduced in some concerns where the waste heat of the power plant can be used in the manufacturing processes in the form of low-pressure steam or warm water.

Cost of Steam Power Using Steam Turbines

In most textile mills, the power plant will vary from 1000 to 5000 kw. capacity. There will be some instances where the power used is less than 1000 kilowatts, and some in which the power required will be more than 5000 kilowatts, but for the purposes of this paper, we have considered this range as sufficient for illustration.

For most textile mills requiring plants of less than 5000 kw., the installation of two-story boiler houses, mechanical stokers, and mechanical coal-handling apparatus does not seem warranted to reduce the unit operating costs, which include fixed charges.

For a 5000 kw. plant, the last two columns in Table 1 show the differences in costs between a simple installation and the more complicated plant.

With modern plants, the figures in Table 1 for cost installation and operation are fair, when steam is not used for anything but power.

In many places mills run longer hours than 48 a week, and coal can be de-

Table 1

COST OF STEAM POWER USING STEAM TURBINES IN TEXTILE MILL PLANTS

OPERATING 50 WEEKS OF 48 HOURS EACH OR 2400 HOURS PER YEAR						
Size of Plant, in K.W.	1000	2000	3000	4000	5000	5000
Boiler House, No. Stories	1	1	1	1	1	2
Type of Stokers	Hand	Hand	Hand	Hand	Hand	Mech.
Coal Handling Method	"	"	"	"	"	"
Cost of Plant per K.W.	$178	$152	$130	$120	$110	$133
Coal Used, Lbs. per K.W.Hr.	3.1	2.7	2.6	2.5	2.4	2.2
POWER COST, BURNING COAL						
Yearly Cost, per K.W.	$55.00	$47.00	$44.00	$41.00	$39.00	$38.00
Cost per K.W.Hr. in cents	2.56	2.18	2.04	1.90	1.81	1.79
POWER COST, BURNING OIL						
Yearly Cost, per K.W.	$58.00	$48.50	$45.00	$42.00	$39.00	$43.00
Cost per K.W.Hr in cents	2.66	2.24	2.10	1.94	1.81	1.95

livered at $4.00 a ton, and construction costs are less.

With 54 hours a week and $4.00 coal, and no change in cost of plant, 1000 kw. could operate at $47.44 a kilowatt, or 1.95c a kilowatt-hour, all costs included; and 5000 kilowatts could operate at $33.40 a kilowatt, or 1.37c a kilowatt-hour, all costs included.

Effect of Use of Waste Products

It has been common practice for many years to use exhaust steam of non-condensing engines and steam from the receivers of compound engines for manufacturing purposes and for heating buildings.

The saving by the use of exhaust steam, which would otherwise go to waste, is considerable. In some mills, especially colored mills, if the power is not produced by steam, so that the low-pressure steam can be used for manufacturing purposes, it would be necessary to maintain a boiler plant of sufficient size to produce an equivalent amount of exhaust or receiver steam thus used.

The bleeder type of steam turbine lends itself to this manner of running better than the reciprocating steam engine, and supplies steam free from oil for process work.

In addition to saving in coal, there is some saving in fixed charges on a portion of the boiler plant, and attendance in the boiler house.

The reduction effected by the use of low-pressure steam upon the net cost is shown approximately in Table 2.

Table 2

REDUCTIONS IN COST OF POWER, EFFECTED BY THE USE OF EXHAUST OR BLEEDER STEAM

Low Pressure Steam in percent of Total.	25	50	75	100
SAVINGS IN POWER COST				
Yearly savings, per K.W.	$7.00-$10.00	$12.50-$13.50	$18.00-$23.50	$23.50-$30.50
Savings per K.W.Hr. in cents	0.33 - 0.45	0.58 - 0.63	0.85 - 1.10	1.08 - 1.42

Water Power

The cost and, consequently, value of water power depend upon a variety of factors, but the essential fact is, whether, considering the combined result of all these factors, power can be produced and delivered as cheaply in this manner as by any other method.

The chief items affecting the cost and value of water power are as follows:

1. The quantity of water and the uniformity of flow during the year or a succession of years.

A power whose flow is constant is the most valuable.

If the flow is variable, it must be supplemented by steam or other power, and the value diminishes as the need of supplementary power increases. The variability may be so excessive as to make the cost of maintaining and running a double plant more expensive than it would be to produce the same amount of power by steam power alone.

2. The power which can be derived from a definite quantity of water increases directly in proportion to the head, and the cost of development increases per horsepower as the head diminishes.

3. The location of the power has a large effect upon the value, but, as stated before, the ability to transmit power electrically has rendered useful and of value many powers which otherwise would be valueless. It is now possible, in many cases, to so locate a mill as to get the desirable features and to run it electrically by water power, but even in such a case the location of the water power has a large effect upon its value, for the cost of transmission lines will be greater for larger distances to be run, and the line losses greater.

4. The use of exhaust steam and overflow water from the condenser for manufacturing purposes tends to reduce the net cost of steam power and therefore to reduce the value of water power for this particular use.

The chief items in the yearly cost of power are:

1. Fixed charges, as interest, depreciation, insurance and taxes, on the development.

2. Repairs and maintenance.

3. The cost of supplementary power, if any is necessary to make up for the fluctuation in water power.

4. Attendance and supplies.

Cost of Hydro-Electric Power

No definite sum can be fixed as the cost of water power, as this depends largely upon the conditions which affect the cost of the development. Each case must be considered on its own merits. As the chief cost of water power is usually the fixed charges on the cost of the development, the first cost is the most important item for consideration.

In a development substantially made, the fixed charges for interest, depreciation, insurance and taxes, and the repairs may be as low as 9 per cent, with a short transmission line, to 12 per cent with a long line. For the purposes of this paper, they are assumed at 10 per cent.

One hundred dollars a kilowatt would be considered a low cost development. The cost in most instances would be greater than this, and some developments have been made in which the cost has been so great that it has been impossible to make it a paying investment until the capital charges are scaled down.

A uniform power development at reasonable cost is a valuable asset which bids fair to increase in value as time goes on. A uniform power at high cost may not be profitable. A varying power at high cost is pretty sure not to be profitable.

Table 3 shows in a general way the cost of power under varying conditions of construction cost.

The above costs are for current on the switchboard in the generating station. The effect of transmission losses is to increase the cost of power delivered to the mill in proportion to the per-

TABLE 3

APPROXIMATE COST OF UNIFORM HYDRO-ELECTRIC POWER

DELIVERED AT POWER PLANT SWITCHBOARD

Size of Plant in KW.	1000	2000	3000	4000	5000
Assumed Plant Cost, per KW.	$100	$100	$100	$100	$100
Power Cost, per KW per year	$14.00	$13.25	$12.50	$11.75	$11.00
" " " K.W. Hr. in cents	.65	.61	.57	.53	.50
Assumed Plant Cost, per K.W.	$200	$200	$200	$200	$200
Power Cost, per K.W. per year	$25.00	$24.35	$23.45	$22.60	$21.75
" " " K.W. Hr. in cents	1.17	1.13	1.09	1.05	1.00
Assumed Plant Cost, per K.W.	$300	$300	$300	$300	$300
Power Cost, per K.W. per year	$36.20	$35.30	$34.40	$33.55	$32.65
" " " K.W. Hr. in cents	1.70	1.65	1.60	1.55	1.50

centage of loss on the transmission lines. These losses for short lines would be roughly 5 per cent, and for long lines 10 per cent.

Adding 10 per cent to the last set of figures in the preceding table, we have, as shown in Table 4, the approximate cost at the end of the line, assuming the cost of plant and line at $300 a kilowatt.

Effect of Variable Power

That portion of the power which is uniform and which can be depended upon all of the time is called "permanent power" or "primary power," and that power which is variable and cannot be furnished all the time is called "surplus or secondary power."

It is the latter kind of power which we will now discuss.

The effect of variable power is the necessity of a supplementary plant of sufficient capacity to make up the deficiency of water power, or the purchase of electric current for this purpose.

In some few instances, the variation of flow is so great that the extreme low flow is insufficient to generate any useful power, and sometimes the back water may be so great as to reduce the working head to such an extent as to make it useless for power. In such cases as these, it would be necessary to maintain a supplementary plant of the same capacity as the primary plant, costing, roughly, three-quarters as much per kilowatt as given for regular steam power; for the purpose of discussion, say $100 a kilowatt.

Usually there is some permanent useful power in all developments, but all power developed above the permanent must be supplemented as stated above if it is desired to produce continuous power, and there are very few industries which can succeed unless they can be run continuously.

TABLE 4

DELIVERED AT CONSUMERS END OF TRANSMISSION LINE

Size of Plant in K.W.	1000	2000	3000	4000	5000
Assumed Plant Cost, per K.W.	$300	$300	$300	$300	$300
Power Cost, per K.W. per year	$39.80	$38.80	$37.80	$36.90	$35.90
" " " K.W. Hr. in cents	1.87	1.82	1.76	1.71	1.65

The fixed charges on the supplementary plant would go on, whether this plant was used or not, at 12.5 per cent, or $12.50 per kilowatt-year. To this must be added the cost of operating, which, under a varying load, would be less economical than regular steam power, and would cost from $2.30 to $3.25 per kilowatt a month.

The total cost of power in such cases would be approximately as is shown in Table 5.

Every $100 increase in the cost of the hydro-electric development adds $10 a year in fixed charges to the cost of power per kilowatt.

Thus a 1000 kilowatt plant, costing $200 a kilowatt, costs $25 a kilowatt for steady power. If supplemented by steam to its full capacity for five months, the total cost of power would be $53.75. If the cost is $300 a kilowatt, including transmission, the yearly cost, if supplemented for full five months, would be $65 ÷ .90 = about $72 delivered.

In order to determine whether a water power should be developed, and the extent to which it should be developed, a comparison of the total cost of producing the amount of power required by water power, supplemented, if necessary, by steam power or purchased electric current, should be made, with the cost of producing the same amount of power by steam alone or purchasing all of it.

The cost of the water power and the supplementary power must not be more than the cost of steam power alone or purchased current alone.

If considerable quantities of steam or warm water can be used in the manufacturing processes, the amount which can be invested in water power is less than could be for a plain mill.

As the variations in costs and uses are great, each case requires careful study, and there must be kept in mind, so far as can be foreseen, possible future changes in fuel prices and advance in the art.

Table 5

APPROXIMATE COST OF VARIABLE HYDRO-ELECTRIC POWER

POWER COSTS PER KILO WATT PER YEAR FOR HYDRO ELECTRIC PLANTS HAVING STEAM AUXILIARY POWER PLANTS

Size of Plant, in K.W.	1000	2000	3000	4000	5000
Cost of Hydro-Elec. Plant per K.W.	$ 200	$ 200	$ 200	$ 200	$ 200
Yearly Cost, Hydro-Elec. Plant per K.W.	$ 25.00	$ 24.35	$ 23.45	$ 22.50	$ 21.75
AUXILIARY STEAM PLANT					
Yearly Fixed Charges. per K.W.	12.50	12.50	12.50	12.50	12.50
Operating Cost each month per K.W.	3.25	2.75	2.50	2.40	2.30
TOTAL YEARLY POWER COST PER K.W.					
Steam Plant running 1 month	40.75	39.60	38.45	37.50	36.55
Steam Plant running 5 months.	53.75	50.60	48.45	47.00	45.75

Purchased Power

Many mills now have the opportunity of purchasing electric current from some central power station or power company which is producing power either by steam or water power or both.

There are many points of advantage to the mill, if such power can be purchased at a reasonable price, which will not be discussed here.

Assuming that the mill will consider

the purchase of power on a basis of cost of production by its own plant, how much can it afford to pay for the same?

Table 6 shows approximate fair prices for purchased power for plain and colored goods textile mills.

With an established mill with a good power plant all built, the mill has its investment in steam plant to charge off, and it could afford to pay an amount somewhat less than if it were a new mill and could save the investment in steam plant. The amount to charge off will depend on how many years the existing plant would naturally run in an efficient manner, and it can be spread over this length of time or done in a shorter period. If the steam plant is not efficient, no such deduction should be made.

For amounts of power less than 1000 kw., the price which could be paid would increase.

All of the figures presented have been made for textile mills, the load of which is fairly uniform and the service less severe than for almost any other business. Some other kinds of business can pay considerably more for power than textile mills.

General Conclusions

Having made a survey of the possibilities of the production of power by water and steam, or the purchase of electric current, a conclusion can be reached as to what plan should be followed. Each problem requires its own solution.

At the present stage of the art, the following general statements can be made fairly safely:

For Existing Mills

1. Plain mills owning and operating water-power developments of some merit, usually in connection with steam power.

(a) If the water-power plant is old and inefficient, remodel it and thus increase its output.

(b) If the steam-power plant is old and inefficient, and electric current can be purchased at a reasonable rate, purchase current sufficient to

Table 6

FAIR PRICES FOR PURCHASED POWER FOR PLAIN & COLORED GOODS TEXTILE MILLS

Fair prices that Textile Mills could afford to pay for guaranteed power are about as follows:

CAPACITY OF PLANT K.W	RUNNING 48 HRS. PER WEEK. COAL AT $7.00 PER TON		RUNNING 54 HRS. PER WEEK COAL AT $4.00 PER TON	
	COST PER		COST PER	
	K.W. PER YR.	K.W. HR.	K.W. PER YR.	K.W. HR.
Plain Cotton mills using exhaust steam for heating & slashing only.				
1000 KW.	$55.00	2.56 ¢	$47.50	1.95¢
5000 K.W.	$ 39.00	1.81 ¢	$ 33.50	1.37¢
Colored Goods Mills using about 75% of the power plant waste heat.				
1000 KW	$ 32.00	1.47¢	$ 28.50	1.17¢
5000 KW.	$ 21.00	0.96¢	$ 19.00	0.78¢

make up for the lack of power from the water-power plant.

2. Plain mills run by steam power alone.

If the steam plant is old and inefficient, and electric current can be purchased at a reasonable rate, it should be done.

3. Colored mills.

(a) If the water-power plant is old and inefficient, a study should be made to ascertain if it will pay to remodel it, and to make still further use of the water for power. In some cases, where the mill has grown, it has been necessary to conserve all the water for manufacturing purposes.

(b) There is usually so much use for low-pressure steam and warm water for process work, that all or nearly all of the heat rejected from the steam engine or turbine can be used, thus reducing the net cost of power to an amount probably so low that it will not pay to purchase electric current.

For New Mills

1. Plain mills of moderate size can probably purchase current cheaper than it can be generated by an isolated plant at the mills.

2. Colored mills of any size can usually produce power and steam and warm water for manufacturing processes cheaper than they can purchase electric current and produce the required amount of steam and warm water.

DISCUSSION

Sidney B. Paine*: The paper to which we have listened must be of great value, as it contains clear and concise statements concerning a very important question which has been under consideration by textile manufacturers. Mr. Main's discussion is based upon the assumption that the mill is driven by motors. The correctness of this assumption is supported by the census of 1920, which showed that in this country three million horsepower is required to operate our textile mills, of which amount two million horsepower is delivered by electric motors. My own records, which have been kept in detail since 1893, show that on January 1, 1925, the total kilowatt capacity of the generators installed to that date is only about 43 per cent of the horsepower capacity of the motors. In recent years this percentage has been smaller. This must be due in a large part to the fact that a constantly increasing percentage of the current to operate the motors is being purchased from the public utilities. These records contain the names of 145 power companies which are supplying current for this purpose. The New Bedford Gas and Electric Company has been very active in this field. About 120,000 h. p. is required to operate the textile mills in that city. Of this amount 65,000 h.p. is purchased from that public utility. This constitutes nearly 80 per cent of their total output.

In arriving at a conclusion as to whether the power to operate a new mill should be generated by a plant owned and operated by the mill, or should be purchased from an outside concern, there are other matters to be considered aside from the relative cost of the current in either case. The cost of the power is of importance, but there are other items of greater importance. The cost of the raw material and labor is approximately 75 per cent of the total cost of the manufactured product, varying, of course, with the grade of goods. The cost of driving, lighting, and heating the mill varies from 5 to 10 per cent of the total cost. The power plant if owned by the mill adds materially to the

*General Electric Company, 84 State Street, Boston, Mass.

amount of capital required. The capital will be much smaller if this expenditure for a power plant can be avoided, even if the capacity of the mill remains the same, as a higher return can be made to the stockholders if all of their investment is expended in the buildings and producing machinery. If the demand for steam or hot water in the manufacturing processes is not too great, the mill can afford to pay more for purchased power than the cost of power generated upon the premises, provided uninterrupted service can be secured with the minimum variation in voltage and periodicity. This latter is very important, as the speed of the machinery will vary directly with the periodicity.

Power for the Paper Industry

By Joseph A. Warren

Vice-President, S. D. Warren Co., Cumberland Mills, Maine

Paper and printing rank as sixth of the major groups of industries. This year there will be produced over 8,000,000 tons in the United States, of a value somewhere in excess of $1,000,000,000.

The fourteenth U. S. census gives the following figures for primary installed horsepower in various industries:

All industries	29,500,000
Iron and steel	5,500,000
Lumber and timber products	2,360,000
Cotton and woolen textiles	2,330,000
Paper and pulp	1,850,000

Steel and paper mills run twenty-four hours, so that in the amount of power consumed paper takes second place, and in power used in proportion to investment. To output or in proportion to employees, paper takes first place among major industries. The industry also uses large quantities of process steam. Beyond this, few general statements can be made. Mills vary greatly because of the character of their product, requiring different processes, and this, with local conditions, gives each mill its individual power problem. They are grouped as paper mills because they all make a continuous web of paper from vegetable fibre on a so-called paper machine. A paper machine is always the same in principle, but varies greatly in size and detail.

In order to understand the power problem, it is necessary to recognize two distinct steps in the industry:

First—Preparation of pulp.

Second—Making of pulp into paper.

The two processes are not necessarily connected in one mill. A great deal of pulp is produced for the market and supplied to the so-called converting paper mills. There are certain economies in the combination of pulp and paper mills, as it eliminates the cost of drying and packing the pulp for shipment, and gives the advantage of larger units in the combination of steam and power plants.

Wood is the raw material for over 90 per cent of the pulp produced. In addition to this perhaps 30 per cent of all paper used is collected and returned to mills to be remade.

Two kinds of pulp are made from wood by distinct processes.

First—Mechanical pulp, made by pressing the logs against a grindstone in the presence of water, a cord producing from 1800 to 2000 lbs. of pulp at an expenditure of about 70 hp. per ton per twenty-four hours.

Second—Chemical pulp, made by digesting the wood after it is cut into chips, with powerful chemicals in contact with high-pressure steam. A cord of wood in this process produces from 1000 to 1200 lbs. of pulp. After cooking, the pulp is usually treated with bleaching powder.

Wood as a raw material was introduced about 1870. At that time our consumption of paper was under 400,000 tons. The discovery of an abundant and cheap raw material greatly stimulated the industry and has brought about the enormous consumption of printing papers.

News print makes up about 33 per cent of our total consumption. It is

made of mechanical pulp mixed with a small percentage of chemical pulp. It is made in mills of enormous size, combining the pulp and paper processes. The location of the mill must be such as to afford cheap wood and power. Nearly all use water power, and the industry has been a pioneer in large water-power developments. A news mill will use about 70 kw. per ton of paper per day, 80 per cent of this for grinding wood. The grinders are usually directly connected to water wheels, but where the head is not suitable, or local conditions do not favor this arrangement, motors are used in large units. The making of the news paper from the prepared pulp is similar to that of other papers to be described presently in more detail, except the machines are of enormous size, some 20 ft. wide, running at 1000 ft. per minute.

Paper board mills produce about 30 per cent of our total paper. This is produced largely from old papers in converting mills with a comparatively small consumption of power. Steam is used for drying in sufficient quantity to yield by-product power very nearly sufficient for all requirements. The mills are therefore located near large centers, having in view a supply of material and proximity to market.

Book paper makes up about 12 per cent of our total consumption, and writing paper about 4 per cent. The process is similar for both. These papers are made from bleached chemical fibre, with a rag content for the highest grades. If the pulp is made on the premises, it is pumped to the paper mill and goes through the so-called beating process, requiring a considerable amount of power, in units of about 100 hp. The stock next passes to the paper machine, where it is dewatered, first by gravity and suction on a woven wire; next, by pressing on a felt between heavy rolls to a water content of about one-third by weight, and then passes to drying cans where the remaining water is evaporated with steam. For the higher grades of book paper it usually goes through several supplementary processes to give it the desired surface, and is then cut into sheets. Throughout the process, power is required in both large and small units, and nearly all mills are driven in part by electric motors.

A book mill, making its own pulp, will require power and steam about as shown by the following table:

	Kw. per ton per day		Steam—lbs. per ton
Pulp mill	6.3	(cooking)	6000
		(evaporating)	4200
Beaters	21.0		—
Machines	2.5		6000
Drying	—		1570
Miscellaneous	3.0		1080
Electrolytic	5.2		1300
Radiation	—		3850
	38.0		24,000

The paper machine determines the output of the mill, and everything is organized to obtain full and uninterrupted operation of this machine. There are no idle periods for adjustment or oiling, and everything must be designed and built for constant operation. The driving of the machine, which is properly a succession of machines running in conjunction, furnishes an interesting problem. The speed of the group as a whole must be capable of variation over a considerable range, and the relative speed of successive sections must be under control so as to provide the proper tension of the web of paper. On large, high-speed machines, which overtax the limits of the ordinary mechanical drive, the above requirements are very nicely met by the use of sectional d. c. motors under a common control.

Book and writing mills usually have some water power. This can often be used efficiently through a line shaft, driving beaters. For other purposes the tendency is now to use motors operated by power generated either locally or in

many cases from outside sources, the characteristics usually being such that they can tie in with the power systems in their vicinity. Water powers sometimes fail, and very commonly a steam power plant is installed for emergencies. It is very common practice to drive paper machines with a steam engine, using the exhaust for drying. With the efficiency of modern turbines and the practicability of generating steam at high pressures, there is an opportunity for the generation of considerable by-product power. Figures have been given above for the total steam consumption of a book mill. About two-thirds of this steam is utilized for drying, requiring but a few pounds pressure. The passage of this amount of steam through a turbine, reducing, say, from 200 lbs. super-heated to 10 lbs. exhaust, will yield theoretically nearly one-half of all the power required. Still more could be obtained from steam at higher pressures.

There are in New England about 175 paper mills, about 125 of those being converting mills. A good many of these started to operate many years ago, before the days of wood paper. They built on streams to obtain water power and water for the process. Rag required a good deal of power for beating. With the substitution of wood pulp, power consumption has been lessened. With some water power available, combined with engines whose exhaust is used, as a rule the cost of power is not a serious item. In New England the cost of coal is a much more important item.

Very large quantities of water are used in the process, and a dependable supply of good water is an essential. Pumping operations for both water and stock are numerous. Pumps, often in isolated positions, are very conveniently driven by motors. Individual motor drives for finishing processes, such as super calendering, coating machines and cutters, are commonly used, and the efficiency of such machines is increased if the speed is variable. This speed is usually within the limits obtainable with a. c. equipment.

DISCUSSION

N. J. Neall*: There is one aspect of the situation at the S. D. Warren Company plant—the electrical—which I would like to mention because I think it exceptional.

This company, which is located near Portland, Maine, began the use of electric power as early as 1889, and, because of the conditions existing in the design of alternating current motors at that time, adopted the 2-phase system—operating at 60 cycles—the 3-phase motor being not then available.

Since then it has developed, in all, for its own use four hydro-electric plants on the Presumpscot River, now one of the most completely developed and best regulated rivers in the country, from which power is transmitted to the mill, where turbo-driven generating units have also been installed as relays. For some time there has also been an electric connection with the system of the Cumberland County Power and Light Company, whereby surplus power (usually hydro-electric from another watershed) could be used, also a mutual exchange of prime power could be arranged for as required.

Important exchange of service has thus been made feasible between these two organizations, especially in times of emergency, and has worked out quite satisfactorily to both. Such a combination is furthermore ideal from the economic standpoint, as it of course results in highly efficient use of available water

*Consulting Engineer, Boston, Mass.

power since a paper mill operates on a twenty-four hour basis at a high load factor.

The Presumpscot River valley is subject to considerable lightning disturbances, and much has had to be done to free S. D. Warren Company from interruptions from this cause. On the whole, however, the record of operation in this plant over a considerable amount of years will bear very favorable scrutiny from all angles of the power-supply situation.

The Utilization of Power in the Typical New England Plant

By K. D. Hamilton

Geo. E. Keith Company, Brockton, Mass.

The subject which I am going to discuss is the utilization of power in the typical smaller New England plant. No plant is too small to receive consideration in this discussion, for every manufacturing institution must use power in one form or another; and because of the broad scope of this topic it will be necessary to present this paper in generalities.

We will consider, for instance, any plant up to 1000 hp. as a typical unit. There are hundreds of small manufacturing plants using power, but the sum total of the power consumed in these industries more than counterbalances the few large institutions which are in operation in our New England States.

We are entering into a new era of competition, where competitive surroundings require the most efficient operation. Production managers are seeking methods to cut costs which five years ago they would have overlooked because of their insignificance. Power may represent to the relatively small plant an extremely small percentage of the total cost of the unit produced. Today, however, a small saving, based on a reasonable investment, is very attractive to any owner or superintendent.

Let us discuss in general terms the entire field of power, beginning in the boiler and engine rooms and tracing it through the distribution lines to the factory, including not only electric power, but steam which is used for driving power apparatus or industrial process work.

We have two types of power plants in these states. One, which through the installation of new equipment and efficient management has been able to operate at minimum cost. Its efficiency is apparent from its general appearance. We find the direct-connected generator, driven by a turbine or a high-speed Corliss or Uniflow engine. Methods have been taken to reduce heat losses through the application of economizers, stokers, the latest types of boilers, efficient coal and ash handling equipment, and—above all things—efficient management. The owners of the business have appreciated that without the proper appliances men cannot produce results. They have sensed the necessity of furnishing temperature controls, CO_2 recorders, boiler-feed regulators, steam meters, draft gauges, efficient coal-weighing devices, and similar equipment.

This type of plant produces steam at low cost. The boilers are doing better than 10 lbs. of steam (from and at 212° F.) per pound of coal. If engines be installed, they are no doubt consuming 15 to 24 lbs. of steam per horsepower when operating condensing, and from 20 to 30 lbs. of steam when running non-condensing. When plants are of sufficient capacity to utilize turbines, water rates as low as 12 to 14 lbs. are available in the industrial size of equipment.

The larger plants have usually installed water-tube boilers of standard make, where higher pressures can be carried. These are either hand-fired or equipped with stokers, depending

upon the size of the plant. Even this apparatus cannot produce steam at a low figure without intelligent operation.

What a contrast is the other type of plant to the one above described, which has been well managed. We find in some establishments several scattered boiler and engine plants, usually consisting of the old HRT boiler, set about 30 inches above the grate, and a fireman doing his best to fill the entire combustion chamber with fuel.

The brickwork on the back end of the boiler has settled, and the cracks are sufficient to allow infiltration of air to such an extent that it would be impossible to obtain perfect combustion conditions. We find that the ambition of the fireman is to keep up steam regardless of how much coal he burns. The engineer is in the engine room, looking over catalogs, while his engine is groaning away with a knock in the main bearing, and the packing blown out of the stuffing-box on the piston rod. We look at his feed water heater, and we find oil floating on the top of the water. We ask him when he cleaned his boilers out and if he had any scale in his boiler—and we receive the reply that he had at least ½ in. on the back end of the tubes, but he thought that with the new compound which he had just purchased it would come off very readily.

We find the old-type slide-valve engine, or perhaps a Brown or Corliss, running with all the load the piece of junk will carry. We ask the engineer if he ever indicated his engine, and he answers that the owner did not feel that he could afford to buy an indicator.

It is for this type of plant that the greatest benefit can be obtained by studying power—its production and utilization. We talk about the fuel shortage. If everybody would see that fuel is used as economically as possible, within reasonable limits of capital investment, fuel consumption would be reduced and plants would be operating efficiently.

Efficiency in the Boiler Room

Efficient units have already been devised by the manufacturers for making possible savings in power generation. The greatest saving today can be made in the boiler room. Go over your brickwork and see that there are no air leaks; enlarge the combustion chambers in old boiler settings to insure proper mixture of gases, in order that they may be burned to obtain the maximum amount of heat. Check up flue-gas temperatures, to see that heat is not being wasted up the stack. Obtain as high a boiler feed temperature as possible, and provide your engineers with at least a water meter and a coal scale, to determine what his evaporations are.

I shall never forget the first day I crawled through an 11″ x 15″ manhole into an HRT boiler to find out the conditions inside, because the engineer said the boiler was clean. I found scale on the back end of the tubes and rear head at least ½ in. thick. I found oil near the boiler feed pipe, where the water discharged into the boiler. Upon looking into the firebox I found a patch on the first row of rivets; and I finally came to the conclusion that either the operating engineer lacked ambition to keep his plant in condition, or the owners did not realize the inefficient methods which were prevailing.

We find in the inefficient plants such items as pipe coverings omitted from flanges, from return lines, and in some cases even from high-pressure supply lines. Maintenance men know what it is to retube boilers, to repair brickwork on Sundays and holidays, to rebore cylinders after some engineer has found that he can cut down on his lubricating oil, to repair valves and main belts on engine drives, where operating engineers had failed to carefully preserve the equipment.

All of these problems are before the manufacturer today, and he wonders if he can afford to keep such a poor, inefficient plant in operation. No matter how poor the lay-out is, proper su-

pervision, reasonable expenditures for new equipment, and, above all things, co-operation by the management, can make the so-called inefficient plant produce power and steam at extremely reasonable figures.

When the owner is faced with the operation of an old plant, he has before him the problem of purchased versus manufactured power. If he has a large exhaust steam load, or use for steam in industrial processes, he knows that with a reasonable investment he can undoubtedly produce power at a lower cost than it can be purchased. Other plants where there is not a balanced load between steam and power find that it may be cheaper to buy power and to furnish steam for industrial use from their own boiler plants. The important question before the owner is, "Shall I make additional capital investment for power apparatus? Could I not use that money in my plant for productive machinery and obtain a greater return on the investment?"

For the efficient plant, which has had the proper executive control, these problems may be readily answered through a report, embracing the arguments on both sides of the question. In the case of the inefficient plant, however, the owner does not know which way to turn. The lack of records in some power plants of reasonably large size is appalling.

I hope as one tangible result of this meeting, that those of us from the industries will go back and look over the records which are kept in the power department; and if we cannot find intelligible figures, install some system to give us the facts, so that we may know what we are doing, and how much it costs. The average manufacturer knows that his power department costs him a certain amount at the end of the year, but he does not know what it costs him to produce a pound of steam, how much his power is costing, what his evaporation is, or the many other things which the efficient plant keeps as a daily log sheet.

Other problems which the owner must face are the additional labor troubles, and the responsibility for his power department. Many will argue that it is more convenient to snap on a switch and get the service rendered. There is another side to the story, however, in the plant which has intelligent operation, co-operation from the management, and reasonably efficient machinery. In New England we have a heating load of from six to eight months. A great many of the industries require steam for industrial purposes, such as the operation of dryers, cooking, and heating. Where the steam load can be balanced against the power load, power can be produced with modern machinery at extremely low figures, and will show the owner an appreciable saving over purchased power.

We all must maintain a boiler plant for heating. The overhead on this investment must be carried, regardless of additional apparatus, for the generation of power. The slight additional cost for generating equipment may in many cases justify its expenditure, because the power will be obtained as a by-product of the heating load.

Many concerns in this part of the country, especially in the wood-working industries, have sufficient refuse to insure fuel for their entire power load. This is a case where there is no argument as to the method of procedure. There have been other instances, however, where it was cheaper to buy power and to bale the sawdust and shavings, which can be sold at a ready market at higher prices than those which could be realized by utilizing this material as fuel. This goes to show that, in order to solve this problem intelligently, each case must be investigated thoroughly by some competent and unbiased engineer. Each problem must stand on its own requirements, as special conditions influence the decision for every case.

Distribution Problems

We have discussed, in a general way, the problems of the power and boiler departments, but operating men know that that is just half the story. The problems of distribution of electricity and steam from the boiler plant are, in many cases, handled inefficiently, resulting in even greater losses than can occur in the generating station itself.

Electricity is usually developed for the industrial plant at 2200 or 550 volts for distribution throughout the plant. With a scattered plant, the power is reduced to the motor or lighting voltage at each building. Tendencies toward lower motor voltages, especially on individual machines, have been recommended during the last few years because of the hazard which is apparent with the higher voltage. Machines equipped with individual motors operate best at 220 volts. The lighting or heating circuits are usually run at about 110 volts, and the actual voltage at the machine depends upon the line losses and the design of the circuit.

Those concerns using direct current employ rotary converters to transform the electricity to the required voltage. Direct-current motors are not used extensively for transmission drives, but are applied to machines where a variable speed is necessary. The difficulties with direct-current motors do not warrant their use unless absolutely necessary. Commutator troubles, brushes, difficulties in keeping the machines clean, and other maintenance problems, warrant the use of the induction motor wherever possible.

The usual method of distribution from the power house for a series of buildings is from a system of feeder panels. Wherever possible these circuits should be metered, so that the amount of power used in any building can be charged against that particular department. Distribution panels should also be installed in each building for switching circuits to various departments. Here again the individual circuit should be metered, so that departmental charges could be accurately determined. Unless an organized system is laid out, including weekly reading of all meters, to obtain an accurate distribution of power, estimates are made depending upon the connected load in each department.

The induction motor is one of the greatest inventions, and has done more for the advancement of industry than any other system of power transmission. It is universally used and, if given proper maintenance care, its life should be continuous. In purchasing induction motors, however, purchasing agents and engineers should be familiar with the characteristics of the motors which they buy, namely, power factor and efficiency. Other characteristics should be observed, such as size of shaft, size and type of bearings, capacity of oil wells, air circulation, and general appearance of the apparatus. Too little care is given to the efficiency and power factor characteristics in installing motors in most factories.

A few of the maintenance difficulties which plant engineers have to contend with in the operation of induction motors are fuse troubles, possibility of running single phase, installation of compensators or safety switches, oiling and cleaning, bearing trouble, and voltage regulation. If a concern will place one man in charge of the cleaning and oiling of all motors, they will find that their shut-downs will be eliminated, and their repair costs on motor accounts will disappear. At the Keith plant we keep two men busy the entire time cleaning and oiling motors. We have some 1500 motors, running from 100 hp. down, and we are fortunate in being able to say that we have very few burnouts and interruptions in service. We take down motors frequently, refinish the windings with insulating varnish, thoroughly clean out the bearings, renew the oil, and put the motors back into service. Industrial concerns who do not have this type of service should investigate the possi-

bilities, as it will pay for itself in a short time.

Individual Versus Group Drive

The application of the induction motor has an important influence on the power bills and the method of operation. This brings up the much-discussed problem of the individual motor versus the group drive. A few years ago plant engineers throughout the country were trying to install a motor on every machine which came into the factory. This has proved to be poor engineering, and there is just as much of a field for the group drive as there is for the individual motor.

To determine intelligently whether a factory should be equipped with individual or group drives, the engineer should first make a thorough analysis of the power requirements under either system. Accurate estimates should be obtained relating to the expense of shafting, hangers, pulleys, belting, and labor for installation, as against the expense of individual motors, wiring, application of these motors to the machines, and the ultimate cost of power for the operation of both systems. The purchase of spare parts for a great variety of motor sizes has a direct bearing, which might influence a concern toward the group drive, where a few large motors are in operation.

The diversity factor should be given thorough analysis in determining the size of the motor when laying out a group drive. It is good practice when placing a group drive, after determining the total capacity of all machines on a line shaft, to apply a ratio of at least three to one in determining the size of the motor. This, of course, will be influenced somewhat by the character of the machines which the motor is driving, but this ratio has worked out in most instances. This will furnish a motor which will be operating at full load, resulting in high efficiency and power factor.

The flexibility of the individual motor is one of great importance. At the Keith plant we have an entire shoe factory operating without a single group drive in the building. Another factor which is not often appreciated with the individual motor is the breakage of machine parts. We find that motors operating individual machines will blow a fuse when the machine becomes jammed. If these machines had been on a group drive the large motor would have pulled the machine over and damaged some of the machine parts. On the other hand, larger motors of the group drive furnish less maintenance trouble, have larger bearings, operate at lower speed, and if working under full load will operate at higher efficiency and power factor.

Power Factor

Power factor today is attracting the interest of the operating men throughout the country. It is being considered by the central station executives because of the influence it has on the capacity of their plant. Power factor increases the line losses, necessitates the holding in reserve of additional capacity, and consequently keeps the power rate up for every power user. If all industries could be running at 80 to 85 per cent power factor, it would result in lower power costs.

The same problem affects the individual plant. We find that plants are running with power factors as low as 60 per cent. This is particularly true in some industries at the present time where the factories are running at low capacity and the motors are underloaded. Owners are operating more generators and boilers than are necessary, when the power factor is low. Increased transmission losses, poor voltage regulation, increased expense of transformers, wiring and switch equipment are all related to power-factor conditions.

We find that the power factor in different industries varies considerably: shoe factories, 60 to 65 per cent; rub-

ber mills and textiles, 75 to 80 per cent, and wood-working plants 70 to 75 per cent.

There are several ways of improving conditions. One of the cheapest, yet most effective, is an endeavor to bring all motors up to full load. This can readily be done in most plants by rearranging motors already in service. When it is feasible to install a synchronous motor, a steady improvement can be realized. Synchronous motors are better adapted for steady loads such as air compressors, exhaust fans, pumps or similar equipment, where continuous operation can be obtained. Static condensers can be utilized to good advantage by floating them on the line, with a resulting appreciable increase in the power-factor percentage.

Illumination

Light, as well as power, is one of the problems of the operating man today. Efficient illumination is directly related to production costs. Many plants have been able to increase their production from 10 to 15 and even 25 per cent through proper illumination of the machines. Correct lighting has a direct influence on accident prevention, and those concerns which have made an intense drive in reducing accidents find that very satisfactory results can be obtained through proper illumination. General illumination is finding a reception in factories today. The elimination of drop cords and individual lights is recommended in many industries. The elimination of shadows, a flooding of light on the work at constant intensity, is furnishing better working-conditions than the individual lamp.

Electric heat is fast finding its way into factories, replacing steam. This has come about through the possibilities of automatic temperature control and constant regulation, which is not apparent with steam. Higher temperatures can be obtained by the application of electric heat than could be realized even with superheated steam.

Distribution of Steam

The distribution of steam from a boiler plant, for heating and process work, should be designed with the same care and engineering skill that is employed in electrical transmission, because the losses through inefficient installation and use of materials may be enormous. A series of tunnels from the power house to the factory provides the most permanent equipment for distribution. Tunnels should be of sufficient size to house all of the pipes, cables, and wires, and still leave sufficient room for the workmen to make the necessary repairs.

All main feeders for steam to buildings, either for high pressure or heating, should be equipped with steam meters, so that the cost of the steam delivered to any particular building can be determined. Accurate figures can then be made, charging against each building the amount of steam delivered. Split-tile conduit, when properly installed, furnishes an efficient method for steam distribution, provided the piping is thoroughly insulated. Some concerns erect steam piping on poles and transmit steam many hundreds of feet with a loss of not over 10 per cent. The piping, under these conditions, must be insulated against zero temperature.

Too little stress is paid today, in some industries, to the value of pipe covering. Each pipe, regardless of the temperature or the pressure of steam delivered, should be insulated. The loss incurred through inefficient pipe covering is tremendous throughout the country. Every heat unit that can be saved through efficient pipe covering is reflected in a material saving back at the coal pile.

The mechanical difficulties of steam traps are well known to most maintenance men, but there are certain principles which must be involved in the reclamation of condensation. Many plants today are throwing away their high-pressure drips and returns from heating systems because they feel it does

not pay to return this water to the boilers. This is one of the greatest sources of industrial waste. Every plant should save this condensate because of its heat value.

The cost of industrial steam will vary with the type of plant involved, but here in New England steam can be produced at prices from fifty cents to one dollar per thousand pounds including overhead charges. These prices are dependent upon the price of coal, methods of distribution, and type of boilers.

Conclusions

In drawing conclusions, I would like to bring out two or three of the outstanding facts:—That steam power can be produced in New England in competition with central stations, provided there is a balanced load between the power and steam requirements; and that plant engineers and operating men can make large savings through intelligent utilization of induction motors, the application of the individual or the group drive, and a thorough understanding of the problems of power-factor correction. The utilization and distribution of steam presents one of the most serious economic problems because of the enormous wastes which are now being made by the industries. The importance of the plant engineer is increasing each year through the appreciation of power problems. If owners will co-operate with their engineering departments, and furnish them with the necessary machinery and apparatus, many economies can be made which will reflect themselves in lower production-costs.

DISCUSSION

Dr. Samuel W. Stratton*: Mr. Hamilton has not drawn too dark a picture, as this condition certainly exists in all parts of the country, especially in the small units of industry.

As I have had the privilege of listening this afternoon, it has recalled the time when scientific men began to meet together for co-operation in scientific work. It has long been the custom for men working in any particular field of science to get together, compare notes, and exchange ideas. Then followed the engineer, with the organization of the great engineering societies. Quite recently, within very recent years, industry has adopted the same practice. The various units of an industry have learned that they can best solve many problems by working together, not as competitors, but by team work, and if this plan is kept up, the pooling of their interest in the solution of technical problems, it speaks more for the future progress of American industry than any other one thing. I have never seen a better example of it than this afternoon. We have had given here the statistics and data that are of interest to the engineer, the operator, and even the owner of the mill alike. These men are getting together more than ever before. The operators and owners are taking a great interest in these engineering and technical questions, and I have no doubt that many of them had their representatives here this afternoon.

*President, Massachusetts Institute of Technology, Cambridge, Mass.

Advantages and Disadvantages of High Steam Pressure in Industrial Plants

By Joseph Pope

Stone & Webster, Inc., Boston, Mass.

For the purpose of this discussion a high steam pressure will be considered to be any pressure in excess of 200 lb. per sq. in. Although there are some exceptions, that is the maximum pressure commonly employed in present-day industrial practice.

An industrial plant will be defined as a steam plant which supplies both power and steam to a manufacturing process. A plant which generates power only is in the same class as the central station power plant. The same arguments for and against the adoption of a high steam pressure apply in both cases and are outside the scope of this paper.

Kinds of Industry

Even with the above limitation there still remain a great variety of industries requiring a supply of process steam and either mechanical or electrical power. Among them might be mentioned oil refineries, sugar refineries, woolen mills, rubber works, bleach and dye houses, finishing mills, chocolate and candy manufacturers, soap works, chemical works, paper mills, roofing plants, salt mines, sulphur mines — to continue would be almost like calling the roll of industry.

Few, indeed, in all the long list are so fortunate as to have their need for power and for steam correspond so exactly in quantity and time that the whole of one may be generated in supplying the other. The remaining industries fall into one, or possibly, at different times, into both, of two classes: Those with demands for steam in excess of their power needs, and those which need more power than can usually be generated with the amount of steam that is sufficient for process purposes.

This latter class has a particular interest in the possibilities of high pressure, for if through it they can obtain more power from the same quantity of steam, it may be the most economical way for them to get it. As competitive alternatives there are to be considered, however, the central station, a local low-pressure condensing plant, and the oil engine.

It makes a great deal of difference whether the project being considered is an entirely new one or whether it is a going concern with appreciable investment in existing apparatus with considerable life expectancy. It also makes a great difference how fast the concern is growing as affecting what it may be willing to scrap, the kind of industry it is, its general economic and financial policy, the kind of load factor it operates on, both daily and seasonal, the pressure at which process steam is required, how the process steam is used, where it is used in relation to the power-generating plant, the kind and cost of fuel, and the class of labor available. In other words, it all depends on circumstances. Every plant is a separate problem, requiring careful and complete individual study before the right solution may be reached.

The process heating requirement of most industries is satisfied by the use of relatively low-pressure steam, 15 lb. gauge or less usually sufficing. Some

require about 80 lb. gauge, and a relatively few find as much as 135 lb. necessary, but this latter pressure seems to be about the present upper limit. It is, of course, possible that technical development in the industries may call for even higher temperatures than are obtainable with 135 lb. steam, but there are a number of other methods of heating which are especially competitive at the higher temperatures, such as electricity, gas, and direct-heated oil. It might be said in passing that there are probably more opportunities for advantageously reducing the steam pressures employed in existing processes than there will be calls for raising pressures to meet new conditions.

Theoretical Considerations

It will be interesting to examine the steam tables to see what higher pressures mean in the way of temperature and heat availability. As more vivid mental pictures are conveyed by curves than by tables of figures, several sets of curves have been prepared to show the properties which it is desired to investigate.

Figure 1 shows the temperature and total heat as given in the tables over the entire range of absolute pressure from zero to the critical 3200 lb. per sq. in. One pair of curves is for saturated steam, the other for steam superheated to 700° F.

It will be observed how rapidly the temperature of saturated steam increases with pressure in the lower range, but how slowly it does so in the upper range. At 140 lb. per sq. in., the temperature of saturated steam is one-half as great, by the Fahrenheit scale, as it is at 3200 lb. Up to 400 lb., only one-eighth of the total possible pressure change, more than six-tenths of the temperature change has occurred. At about this same pressure of 400 lb., saturated steam contains its maximum total heat. The temperature of steam superheated to 700° is, of course, constant, but its total heat continuously diminishes from the lowest pressure of present interest until the superheat

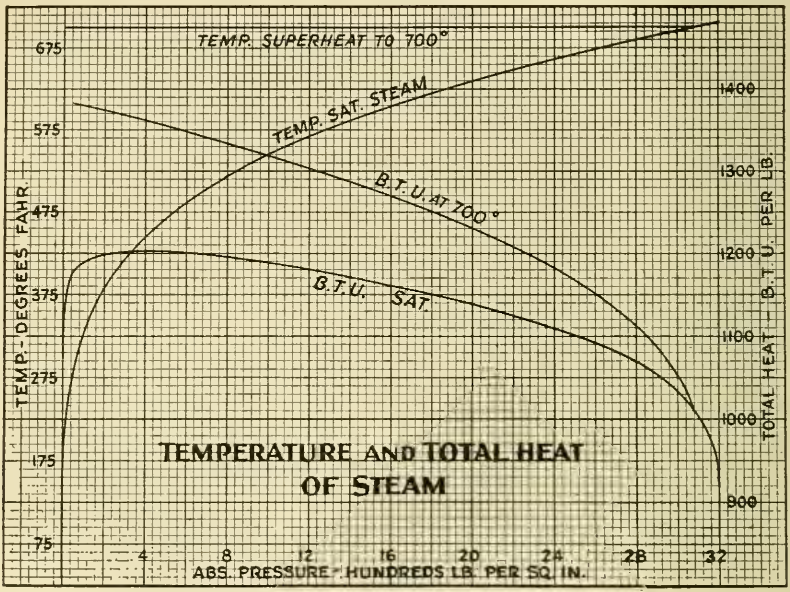

Fig. 1

finally reaches zero at 3075 lbs. pressure. It must be confessed that some liberties have been taken with the steam tables in constructing this latter curve, as none that were examined gave the total heat of superheated steam for pressures higher than 800 lbs.

Figure 2 is a skeleton Mollier or total heat-total entropy diagram. Lines of constant absolute pressure are given

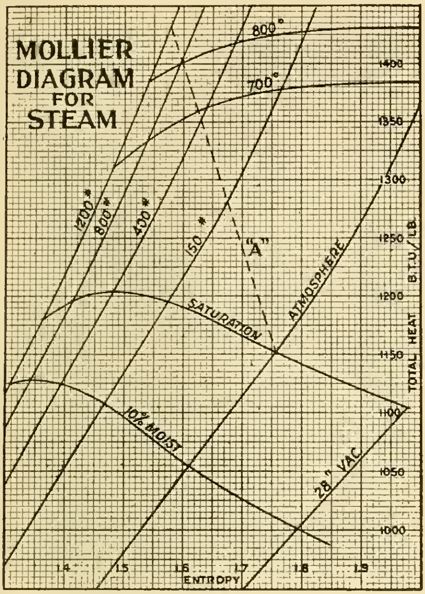

Fig. 2

for 1200 lb., 800 lb., 400 lb., 150 lb., atmospheric, and 2″ Hg., and constant condition lines for 10 per cent moisture, saturation, and 700° and 800° total temperature. The 800° curve is included because no one will seriously question that it is the present upper limit of temperature, and the pressure lines are stopped at 1200 lbs. because few will be interested now to venture to anything higher.

It appears probable that if high-pressure steam is used in an industrial plant it will be for the most part on a simple Rankine cycle, and there will be relatively little regenerative heating of the boiler feed or reheating of the steam. If a turbine is used that exhausts at atmosphere or above, the feed will doubtless be heated by the main or auxiliary exhaust steam, and little is to be gained by higher-stage extraction for further heating. This is particularly true, as the exhaust will be wanted as dry as possible for process purposes, requiring the presence of superheat in the turbine from throttle to exhaust. If further use is to be made of the steam for power purposes before all or part of it goes to process, there may be extraction heating of feed or reheating in the lower pressure ranges. This does not, however, affect the problem under consideration here. We may, therefore, read directly from the Mollier Diagram of Fig. 2 the heat available through the adiabatic expansion of the Rankine cycle.

Figure 3 gives three pairs of curves of available heat for varying initial steam pressure expanding to three different exhaust pressures, 150 lb. absolute, atmosphere, and 28″ vacuum. The lower of each pair of curves is for steam of 700° F. initial temperature, and the upper curve is for 800° F. temperature.

It will be noted that when the back pressure is low, a very great part of the heat available by expansion from the highest practical pressure, which for now we will call 1200 lb. per sq. in., becomes available at some much more moderate initial pressure. For instance, there is a heat drop of 345 B.t.u. from 1200 lb. and 700° to atmosphere. From 200 lb. and 700° to atmosphere the heat drop is 245 B.t.u., or 71 per cent as much. Similarly, from 1200 lb. and 200 lb. to 28″ vacuum, the heat drops are respectively 484 B.t.u. and 412 B.t.u., the second drop being 85 per cent of the first.

However, with a high back pressure, say 150 lbs., the available heat from the 1200 lb., 700° initial condition is 190 B.t.u., and from 200 lb., 700° it is 40 B.t.u., or only 21 per cent as much. This somewhat involved analysis is hardly necessary to prove that

plants which require high back pressure have the most gain from high initial pressure. It does give a clearer idea, however, of the relative gains from high pressure under the several conditions discussed.

No attempt has been made in the foregoing to apply efficiency factors to the available heat drops in order to determine the actual heat consumption and the true final condition. That, of course, should be done when a specific problem is at hand, but the general conclusions which have been drawn would not be altered by such procedure. When dry exhaust steam at a given pressure is required, it will be necessary to work backwards with an assumed probable efficiency factor to determine the initial pressures and temperatures necessary to produce it. The line "A" on the Mollier Diagram is the locus of the initial pressure and temperature conditions which will result in a dry exhaust at atmospheric pressure with a constant turbine efficiency of 70 per cent. Several such curves for various constant efficiencies may be drawn and a cross curve put on them indicative of the different efficiencies expected with the various throttle conditions. The general shape of such a cross curve would be convex upward and to the right.

In the matter of turbine efficiency as affected by high pressure, it is interesting to note that the effect on non-condensing machines is less serious than on condensing units with the same inlet conditions. In other words, industrial plants are likely to fare better in this one respect from high pressure than central stations, although there are means of overcoming the difference which the central station may employ. An increase in pressure increases the frictional losses in a turbine stage and consequently reduces the efficiency. This disc friction is proportional to the fifth power of the diameter and directly proportional to the density of the steam in which it revolves. There are also leakage losses over blade tips or through diaphragm packing that increase with pressure. Higher pressures

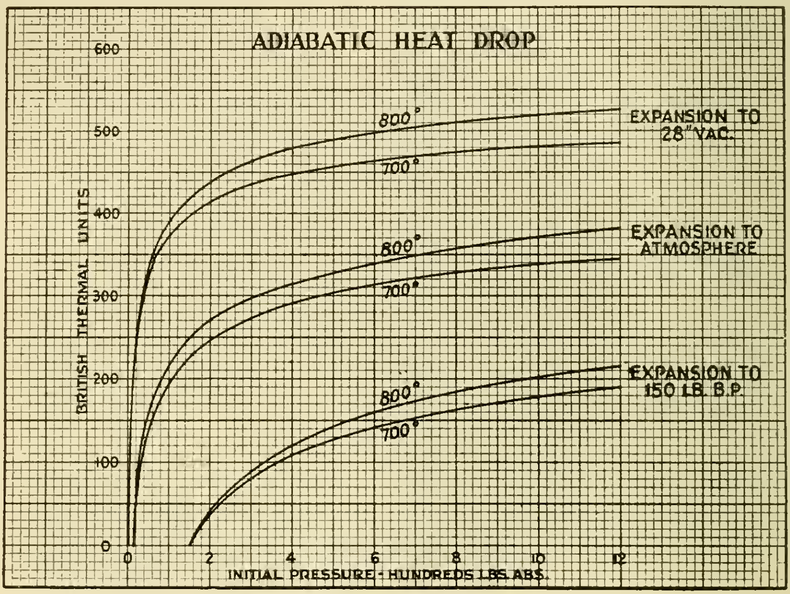

Fig. 3

occur only in the earlier stages of a turbine, and the above increases in stage losses are therefore confined to those stages.

The low-pressure stages, however, are subject to another form of inefficiency due to the presence of moisture in the steam. If it be admitted that some given initial temperature is the maximum permissible, it follows that with increasing pressure the allowable superheat is reduced. Under these conditions moisture forms in the turbine at an earlier stage with high pressure than with low, and the efficiency is adversely affected by the presence of more moisture in more stages. A condensing unit is therefore subjected to both forms of additional loss consequent upon the use of high steam pressure. Reheating has been adopted as a means of overcoming the effect of moisture in the low-pressure zones, but it adds considerable expense and operating complication, warranted only under favorable conditions. Non-condensing, or at least high back pressure units, such as are particularly adapted to industrial conditions, may avoid the moisture loss, provided they use superheated steam.

Practical Considerations

The use of higher steam pressures involves the use of more heavily built boilers, heavier steam and feed water piping and valves, different kinds of joints, and heavier and more powerful feed pumps. It is true that in some cases this apparatus may be of less capacity than if lower pressures were used, and thus partially compensate for the additional cost of the more rugged equipment. However, in the industrial plant the need is usually for a given quantity of steam for process work, and advantage of the lower water rate of the high-pressure prime mover is taken, not to reduce the boiler sizes but rather to increase the turbine size. The industrial plant, therefore, must stand the full cost of the more expensive high-pressure equipment.

Boilers are not now built commercially for pressures greater than 600 lb. There is one 1200 lb. boiler in the Edgar Power Station at Weymouth. There is another in the plant of the Consolidated Safety Valve Company in Bridgeport. Others are under consideration, but it cannot be said that the construction of boilers for that pressure or for higher pressures is as yet on a production basis. There are about forty boilers in service designed for 600 lb. and a relatively large number built for 400 lb.

Boiler prices plotted against working pressure do not make a smooth curve for the reason that it is, as a practical matter, impossible to build a boiler equally strong in all its parts, like the "one hoss shay," and just exactly suited for the designed pressure. The same weight of tubes and class of fittings serve for a considerable range of pressure, and the change is in wide steps rather than in narrow ones. The following table gives the comparative costs of three different types and makes of boilers of about 1000 hp. rated capacity. The costs are given in percentages, the cost of a 200 lb. boiler being taken at 100 per cent in all cases. The fact that boiler "B" outstrips the other two in percentage price increase with pressure is not due to the fact that it actually costs more, but because in the lower pressures it costs less.

The same table shows the way typical valves and fittings and motor-driven centrifugal boiler feed pumps vary in price with working pressure. There is no thought that the items selected cover the entire range of size or type, but they are, at least, representative.

A reasonable deduction from this table is that equipment affected by the steam pressure costs today about 40 per cent more for 400 lb. working pressure than for 200 lb. There are, of course, many other items that enter into a complete steam plant upon which the steam pressure has no direct effect. There will be, however, a tendency toward

Relative Cost of Equipment for Various Steam Pressures

Water Tube Boilers

Working Pressure Lbs. per sq. in.	Per Cent Price Boiler A	Boiler B	Boiler C
200	100	100	100
250	105	110	—
300	123	124	—
350	128	—	—
400	138	164	136
450	146	—	—

Valves and Fittings, Cast Steel

Standard	Type Joint	Working Pressure	Per Cent Price 10″ Gate Valve	10″ Tee	10″ Flange
American	Gasket	250 lb.	100	100	100
"	Sargol	400 lb.	132	198	165
"	"	600 lb.	222	224	230

Centrifugal Boiler Feed Pumps

Size	Stages	Discharge Pressure	Horsepower	Per Cent Price
5″	3	200 lb.	75	100
5″	4	250 lb.-300 lb.	100	120
5″	5	300 lb.-400 lb.	150	142

greater elaboration and the purchase of equipment of a higher grade than would otherwise satisfy in an attempt to get the maximum thermal efficiency for the high-pressure plant.

Whether the greater power to be obtained from the more expensive equipment will justify the added expense depends, as has already been indicated, on many things. First, what sort of a return does the industry ordinarily expect on its money—is it 10, 15, or 20 per cent, or is it more nearly 100 per cent? Second, how does the industry operate—does it run one 8-hour shift daily, a 10-hour shift, or two shifts, or is it a continuously operating process? Is it subject to seasonal variation or frequent slackening of output? In other words, what is the load factor, how much can the higher-priced equipment work in order to earn its keep?

What kind of labor is available? Can it be depended upon to operate and maintain the higher pressure apparatus safely and economically? If suitable labor can be employed, will it have to be at rates higher than would otherwise suffice?

What kind of fuel must be used and what is its cost? Is it scrap or waste to be had for the cost of handling, or is it expensive coal carrying a heavy freight rate?

What kind of water is available for boiler feed? Many industrial plants—in fact, it is probably true that most industrial plants—either mix their process steam directly with their product, or otherwise contaminate it, or lose it so that the drips are unavailable for return feed. In some of the few cases where this is not so, the drips are so numerous, and so widely scattered, it is difficult and expensive to collect and return them, and it is not done.

A large amount of new water is therefore usually required for boiler feed,

and particular care must be taken to see that it is entirely suitable for the purpose. Scaling, foaming, and priming are much more to be guarded against at the higher pressures than the low, although they are serious enough at all times. It may be that the use of a high pressure will carry with it the need for a water purification process or an evaporator plant of considerable size. Evaporators ordinarily give the better water. When the percentage of make-up is small, so that all the heat in the evaporator vapor can be conserved in the boiler feed, they approach 100 per cent in thermal efficiency, but when the proportion of the total feed that must be in the form of new water is large, evaporators are very expensive to install and to operate.

Where is the process steam to be used, after it is exhausted, or extracted from the prime mover? Many industries now distribute live steam at boiler pressure to widely-scattered buildings, reducing it locally to the required pressure. This permits the use of smaller steam mains and also allows considerable pressure drop in the piping without ill consequence. If the steam is first put through a pressure reducing prime mover and the power "skimmed off," to borrow an expression, there will be a great desire, even with an increased initial pressure, to decrease the back pressure as much as possible. If this is done, consideration will have to be given to the size of the distributing mains, and the possible need of enlarging them.

Examples of the Use of High-Pressure Steam

It is impossible to generalize very far about the use of high-pressure steam, for, as has already been stated, every application is a problem in itself. The widest latitude is open to the engineer to employ such equipment and to perform such operations as best fit the particular case in hand. Straight expansion turbines can be bought for almost any back pressure from full vacuum to 150 lb. Even higher back pressure machines have been supplied in special cases. Machines can also be obtained equipped for extraction of steam from one or more stages in which the pressure may be maintained constant or permitted to vary with the load or otherwise. Steam engines are not quite so adaptable to various conditions, but they can, of course, be operated either condensing or against a back pressure, and it is possible to extract steam from the receiver of a compound engine, and even to maintain the receiver pressure practically constant the while.

In what follows, several illustrations are given of the use of high-pressure steam, or what may well have been such use except for intervening circumstances.

As an illustration of the use of high-pressure steam in a pulp and board mill, the following will be of interest:

The present supply is about 85,000 lb. per hour of saturated steam at 150 lb. pressure. It is used to operate a 500 kw. and a 750 kw. condensing turbo-generator for electric power purposes, to furnish steam to the digesters, and to supply engines driving the two machines. The new plan, devised by the engineer of the paper company, calls for the installation of three 500 hp. boilers built for 425 lb. pressure and 100° superheat, which are to supply steam to a non-condensing turbine of 1500 kw. capacity exhausting at 135 lb. with some residual superheat into a header supplying the paper mill and digesters as at present. Of the existing turbo-generators, the 500 kw. unit is to be scrapped and the 750 kw. machine rebuilt and moved to the new power station with a new unit of the same capacity. These machines will take steam at 135 lb. from the exhaust of the high-pressure unit and will operate condensing. Only one of them will normally be required in operation at a time, but the two will be available in event of trouble with the high-pressure machine, when steam will be supplied through a reducing valve.

On account of the improvement in over-all plant efficiency it is expected that the total steam requirements will be about 20,000 lb. per hour less than at present, although the electrical load will be increased from about 1200 kw. to 1600 kw. through further electrification about the mill.

It is understood that this work is now being undertaken. Quite a handsome reduction in operating costs is anticipated, but it is by no means sure that it will be sufficient to cover fixed charges on the actual cost of the job.

High steam pressure is being used by a chemical company in the Middle West in an isolated pumping plant. A brine, which forms the basic raw material of the company's various processes, is obtained from deep wells along a lengthy strip of country. It has to be pumped through pipe lines into the works, in some cases as much as twenty miles. Heating the brine reduces its viscosity and makes the pumping somewhat easier. It is therefore used as a circulating fluid in the main condensers, in which a low vacuum is carried. The particular pumping plant in question is isolated, coal has to be carried to it by motor truck, and the load factor is very high, so that economy of operation is imperative. A boiler pressure of 385 lb. with superheat has been selected and the prime mover is a 1000 hp. Nordberg uniflow steam engine, exhausting into a surface condenser. The condenser performs the triple function of heating the brine, improving economy by virtue of the vacuum, and saving the condensate for return boiler feed. The engine drives a generator which supplies current to individual well pumps and to the pipe-line pumps installed in the power-plant building.

This same company has a great deal of evaporation and electrolytic work requiring low-pressure steam and direct current power. The present boiler pressure is 150 lb. Saturated steam is supplied to engines driving generators, some of which exhaust into vacuum pans, and others into condensers. The plant operation is continuous and the load factor very high.

The company is now installing two 800 hp. water tube boilers, for 385 lb. working pressure, equipped with superheater and underfeed stokers. Steam at 350 lb. and 150° superheat is supplied to a 4000 kw. De Laval turbine of interesting design, which exhausts into a 28″ vacuum. It consists of three separate turbines through which the steam is passed in series. The high-pressure unit runs at 10,000 r.p.m. It is geared to the front end of the low-pressure unit which runs at 3200 r.p.m. and which is in turn geared to the main shaft operating at 720 r.p.m. The intermediate turbine is also geared directly to the main shaft and operates at a speed of 4500 r.p.m. On the main shaft are connected in tandem a 1000 kw. 60 cycle alternator for general power purposes, and two 1500 kw. 300 volt d.c. generators for electrolytic work. At the normal working load the pressures in the connecting pipes between the high-pressure element and the intermediate is about 145 lb. absolute, and between the intermediate and low-pressure elements the pressure is approximately 16 lb. absolute. Steam can be extracted at these points for other power and process purposes.

This unit will be a very efficient, although doubtless somewhat expensive, machine. Division into three separate elements geared to the load permits each to operate at the most economical steam speed-blade speed ratio and allows the friction losses inherent in the high-pressure steam to be much reduced through small disc diameter.

The Westinghouse Electric & Manufacturing Company have installed a steam turbine in a large industrial plant which is not a high-pressure unit but might well have been one. The reason why it is not is that, as is so often the case, the existing lower pressure boiler plant is in such good physical condition that it could not be abandoned with

economy. The plant in question requires a large quantity of hot water, and the heating is done in three stages, first by the exhaust and then by higher-stage bleed. A constant final water temperature of 210° F. is maintained by regulating the turbine-inlet steam pressure to produce a constant stage pressure in the final heater. When heating 1735 gallons of water per minute from 115° to 210°, the machine generates about 4600 kw. at a thermal efficiency of approximately 95 per cent.

A somewhat similar installation, with, however, interesting differences, is being made for a well-known textile finishing mill. A De Laval turbo unit exhausts into the 10 lb. main, which supplies steam to many processes in the mill. There is not such complete coincidence between power and steam demand, however, that wastage of some 10 lb. steam could ordinarily be avoided. A solution would have been to use a condensing unit of the extraction type, but that would add more expense than the saving warranted. In addition to the 10 lb. steam, the mill also uses considerable 80 lb. steam supplied directly from the boilers through reducing valves. This permitted bleeding the turbine from the first stage into the 80 lb. line, the extraction opening being controlled from the exhaust pressure, so that if more power is required than the current demand for 10 lb. steam will develop, it can be obtained through increasing the extraction to the 80 lb. line. There is some question as to whether this installation could be operated to advantage at a higher boiler pressure. It appears that there is a very good balance between power needs and steam needs now, or at least there is no more spread between them than is necessary to permit keeping the variations of one within the limits of the other. In another situation, however, if there were need for a greater power supply, higher steam pressure would be a means toward getting it.

High steam pressure appears especially to fit the requirements of wood pulp mills. They need large quantities of relatively high-pressure process steam and a great deal of cheap electric power. The necessity of cheap power to a pulp mill has usually been considered to

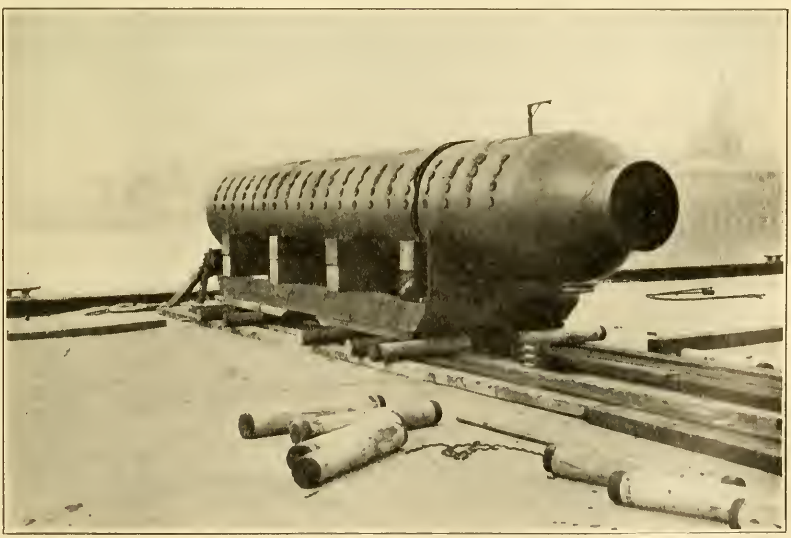

Fig. 4—Drum for High-Pressure Boiler
Edison Electric Illuminating Co. of Boston

mean that only hydro power would do. It is possible for them to install steam boilers for high pressure, say 1200 lb., as at least one is doing, and get a kilowatt-hour for about 30 lb. of steam, expanded to 150 lb. exhaust pressure. This is not a thing to be done lightly, however. Those who are working with steam at this pressure anticipate no trouble that cannot be overcome, but they know thoroughly all the care, all the thought, and all the time that have been expended upon the design and construction of the entire system. They appreciate thoroughly the high order of skill that is required to operate and maintain it. They understand fully how imperative it is that all elements of the system be co-ordinated into one rightly-functioning whole. They feel that anyone not equipped to go to equal lengths should consider carefully before undertaking similar projects.

There already has been considerable said and written about the 1200 lb. installation of the Boston Edison Company, and most engineers are somewhat familiar with it. Figures 4, 5, and 6 are photographs of the boiler, shown here as a matter of collateral interest. Although this is a central-station application of high-pressure steam, and for that reason excluded from this paper, the boiler is doubtless of the kind that would be employed in an industrial use for the same pressure.

An application of high steam pressure under pressure conditions similar to those existing in pulp mills, but where the other conditions may be more favorable, is the addition of a high-pressure plant on top of an existing low-pressure industrial power plant. The exhaust pressure in this case would correspond to the present boiler pressure, presumably from 150 to 200 lb. The initial pressure might be anything up to 1200 lb., depending upon how much additional power is required now or in the future, although use of the extreme higher pressure should be undertaken with great caution. An advantage of approaching the problem from this angle is that the high-pressure boilers need not furnish all the steam. This makes for better conservation of resources at both ends, for the expensive high-pressure equipment can be made to work under the highest load-factor permissible under the plant-operating schedule, and the low-pressure plant need not be entirely scrapped.

Several rubber works have installed high back pressure turbo-generators operating with total pressure drops through them of about 100 lb. These would

Fig. 5—Drum for High-Pressure Boiler
Edison Electric Illuminating Co. of Boston

develop more power on the same steam flow if higher initial pressures were employed, and in planning new power plants for the industry the use of high-pressure steam certainly ought to be investigated.

The Sale of Power

The question might be asked why industries which require a great deal of steam and relatively little power should not install high-pressure boilers and pressure-reducing prime movers for the generation of as much power as possible, the surplus over their own needs to be sold to the public utility.

A counter question of equal propriety is: Why do they not generate power at the present pressures and sell it now to the central-station company.

This is undoubtedly the Utopia of conservation, but there are many real obstacles to be overcome before it can be reached. In the first place there is the matter of selling price. For how much, or perhaps a better way to say it would be for how little, will the industry sell this surplus power to the utility? Obviously the utility can afford to pay not more than its own increment cost of generation. It has no use for power other than to sell it again. If it is already generating millions of kilowatt-hours, it can generate thousands more at very low additional cost, usually for a fuel cost only, and that somewhat lower than the average fuel cost. Utilities are constantly striving to improve their load-factor so that the average cost of generation, transmission, and distribution may be cut down. If they buy surplus power from a continuous-process industry, the load factor of their own generating stations is reduced, and their own unit cost of manufacture is increased. This cuts further the amount they can afford to pay for the surplus industrial power.

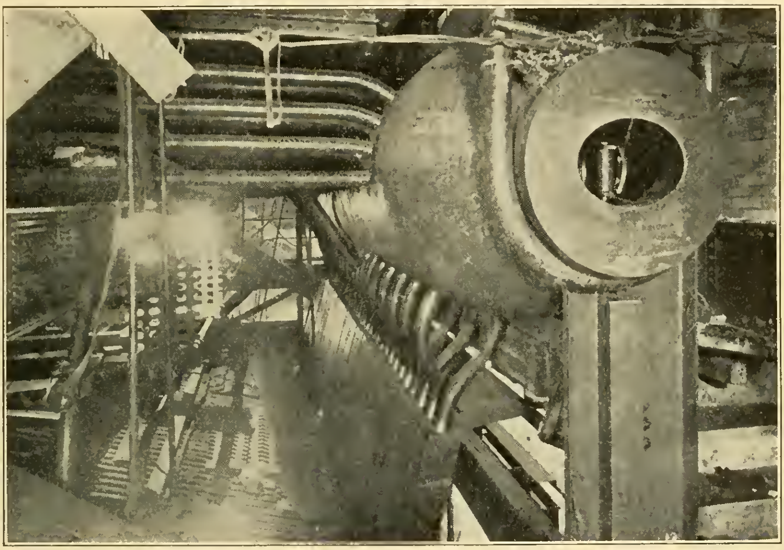

Fig. 6—Steam Drum for High-Pressure Boiler
Edgar Power Station—Edison Electric Illum. Co. of Boston

Unless the industry can put in enough extra capacity to relay against "outages," and unless it can undertake to operate continuously regardless of any slumps in its own business, the power it has for sale is not prime power, and

the utility must be prepared with adequate stand-by equipment to furnish it when necessity demands.

In regard to the actual delivery of the power to the utility, it cannot ordinarily be pumped backward through a feeder such as might supply the industry if it were a customer instead of being a seller. The utility must have complete control of its own distribution net work. It cannot have a number of smaller isolated plants feeding in independently at various points, otherwise feeders that were supposed to be dead might be energized unexpectedly with serious consequences. Nothing but a separate feeder running directly to a substation or main-generating station could be acceptable. Such a feeder, with its transformers, switch gear, and metering equipment, is very expensive, and its cost must be borne by the utility on an already small financial margin, the difference between its own generating cost and the cost to it of the independently-produced power.

To look for a moment at the industry's side of the picture; what is the production cost of its surplus power? It includes, of course, fixed charges and maintenance expense on the extra equipment and on the excess cost of any more-expensive equipment necessary to produce it. It includes the cost of additional supervision, operating labor and supplies, such as it may be. It includes also a portion of the fuel cost. Whenever the production of process steam and of power is carried on together, the division of fuel cost between them can usually be on an arbitrary basis only. Either the power or the steam may bear the whole cost, and the other be considered as having been obtained for nothing, or an attempt may be made to charge the power only with the proportion of the heat units abstracted in its generation, with, of course, its share of auxiliary power costs. If some of the steam is exhaust steam, some bled steam at higher pressure, and some actual live steam, the situation is extremely complicated, and the difficulty of dividing the cost very great.

It is obvious that the margin between the cost of producing the "dump" power, provided it can be determined, and the price that the utility can afford to pay for it, is very small, and likely to be wiped out by many disturbing factors.

Conclusions

In conclusion it may be said that high steam pressure can be shown to be advantageous in some industries but not in others, and that even in the industries where the conditions are generally favorable it may not be suitable in all plants. It must also be remembered that after the engineer has figured and planned with the utmost care, and has demonstrated that an investment in high-pressure equipment can be made to pay high returns, the management may prefer to spend the same sum in productive departments of the industry, or on the Sales Department, whereby even greater returns may be obtained.

DISCUSSION

Irving E. Moultrop*: Mr. Pope's very interesting paper is quite opportune at this time. I am very glad that he has brought out so clearly not only the thermo-dynamic advantages and disadvantages of going to the higher steam pressures, but also something about the capital charges involved.

During my experience as an engineer with The Edison Electric Illuminating Company of Boston, which goes back nearly thirty-five years, I have seen many changes take place. Many times I have seen where some big utility com-

*The Edison Electric Illuminating Company of Boston.

pany, or some large power user, has gone into a new development of some sort which proved very profitable to them, and I have also seen a tendency on the part of some people to go into a similar development because their larger neighbor has done so, without making a careful study to determine whether or not they were justified in following the fashion.

The adoption of higher steam pressures, namely, from 600 to 1200 lbs., by a few of the larger utilities is naturally attracting much attention. I find a number of people are indicating more than passing interest in this development, and I hope that they will not feel they should do something of this sort merely because a large power user has done so. The subject should receive very careful engineering study both from the thermodynamic standpoint and from the standpoint of the investment.

Professor E. F. Miller*: I would like to ask Mr. Pope what Rankine ratio he considers he is likely to get on a high-pressure turbine, and what quality of steam he expects to get at the 350-lb. exhaust pressure; whether it gets down to saturated or whether it is still superheated.

Mr. Pope: You have reference to the Weymouth installation?

Professor Miller: Yes.

Mr. Pope: Well, theoretically we start out there with about 1100 lbs. and 700 degrees, and I think the efficiency ratio is about 70 per cent. I do not recall right now. Perhaps there are others here in the audience who can tell me that definitely. We do not get saturated steam in the exhaust; we still have some superheat. That came about in this fashion: the Weymouth station was to be an operating station, just as good as anybody could build without getting into experiments, and for that reason the boilers were built for a working pressure of 400 lbs., and the turbines for 350 lbs., in fact, they both operate somewhere in between, and we have a standard, high-grade plant. Then, with the idea of finding out what there might be in the use of very high-pressure steam, a 1200 lb. plant was superimposed on the standard plant. Now if you were to start out and say, "We are going to have 1200 lbs. anyhow, and we will divide our pressure range for the very best efficiency," it is possible that you might select some other pressure than 350 lbs. for the intermediate point, but you would not get much different or much better results than we get from the installation as it is, and it certainly was much safer to go ahead on the basis that has been adopted.

Charles T. Main†: I think there is not anything to quarrel about in this paper. Mr. Pope has covered the subject thoroughly and to the satisfaction of myself, and I think to everybody in the audience.

I of course am most interested in industrial plants—power for industrial plants. I have given a good deal of thought to using high-pressure steam, particularly in textile mills. In a central power station the product which is to be sold is power, and that is where the profit is made, and in such a station they can probably afford to go to greater expense in the installation of the plant to get greater efficiency, and there is usually available a class of men to operate the plant that is perhaps of a higher degree of efficiency than may be found in the average industrial plant. The industrial plant is turning out a product for sale to which the production of power is only incidental, and the thing to be considered there in the first place is reliability and simplicity. The last degree of efficiency in the production of the power is not so important as to be sure to have a plant which is reliable, which will run every day with the care which is usually given to the

*Massachusetts Institute of Technology, Cambridge, Mass.
†Consulting Engineer, Boston, Mass.

running of such plants. The cost of shutdowns, even for a short time, is sometimes very expensive.

We realize that in going into higher pressures there are troubles to be anticipated and expenses involved which I think are not warranted in the textile mills, except possibly in the case of a bleachery or dye house, which Mr. Pope has covered.

Mr. Warren told us that a considerable portion of steam is required for process work at about 150 lbs. pressure. It seems to me that in a mill like his it might pay to give very careful consideration to the question as to whether in remodeling their plant they should not go to, say, 400 lbs. pressure, or to the pressure to which we have already arrived in the construction of boilers and in the design of piping.

W. H. Balcke*: I thought it might be some slight contribution to discuss a little where this power comes from, and what it costs to get power by means of extraction or by reduction in pressure, because I did not always have a very clear conception as to what it cost if you turned high-pressure steam through a turbine and got some power and had some steam left.

In the first place, of course you can't get any power without putting in a certain amount of heat, and theoretically that amount of heat is approximately 3412 B. t. u.'s. The heat demand for one kilowatt-hour is 3412 B. t. u.'s, irrespective of turbine efficiency, and aside from radiation and leakage and other similar losses which might come in in trying to operate the turbine.

If you want to take account of these losses and extend the 3412 B. t. u.'s up to 5000, that is approximately the heat cost of every kilowatt-hour that you would get out of such bled steam. If we take that 5000 B. t. u.'s and apply a boiler efficiency of, say, 70 per cent, it means that this power has cost about 7000 B. t. u.'s, or one-half a pound of very good coal. In any ordinary plant you won't get it for any less than that, a fact which I thought it might be useful to point out as being about the measure of the cost of such power irrespective of the interest charges or the equipment that might be demanded.

Frank S. Clark†: Mr. Main, in referring to the textile industry, mentioned the question of reliability and availability. In the East here, with the larger interconnected systems, that question pretty much answers itself, but you do find instances where that is a very important item.

I have in mind one installation in a small town in the Middle West which required, I think, about 8000 kw. The central station supplying the town itself only had about 7500 kw. installed. The power was required by this industry very quickly, and to have gone to the central station would have meant that they would have had to go to the Public Service Commission to get authority to issue the bonds and to make the installation. Anyway, the industrial plant, in a station of that size, could have produced its power as cheaply as the central station. Incidentally, it was located on a very small stream, about a half mile above the central station plant, so that the industry could get the advantage of the cooler condensing water, and I understand that after the plant was in operation the central station suffered somewhat itself.

A remark was made in one of the progress reports of the A. S. M. E. last week which shows the trend of industrial power. This referred to the textile industry and was to the effect that in the last five years, I think, the percentage of purchased power in the textile industry had doubled. I think you will see that ratio constantly increase.

Mr. Pope, in closing his remarks, made a very pertinent statement to the effect that the central station engineer,

*Stone & Webster, Inc., Boston, Mass.
†Stone & Webster, Inc., Boston, Mass.

in figuring his savings, is up against the problem that the same amount of money invested in other parts of the plant must show greater returns. And that is very important.

I have in mind one plant that was investigated some years ago, involving 50,000 installed boiler horsepower, by about a half-dozen different plants located all over the lot, and the investigation showed that savings could be effected which any central station man would have jumped at but to which the industry absolutely turned a deaf ear because they could invest that same amount of money in other ways and get even greater returns than shown for the production of power.

E. B. Powell*: Mr. Pope has very appropriately laid special emphasis on the commercial and operating aspects of higher steam pressures. As mentioned by Mr. Pope, and by Mr. Moultrop in his introductory discussion of the paper, there has appeared a tendency to accept the advance in steam pressures rather lightly as a matter of course, and there have been extravagant statements of the benefits to prospective industrial users. The very exacting operating requirements of these higher pressures are not widely appreciated, and too often such factors as additional investment required and even the actual utilization of the "by-product" power are given but superficial consideration. Careful, detailed analysis of all features as suggested in Mr. Pope's paper is essential to an intelligent selection of operating pressure either for a completely new plant or for an addition to an existing plant.

Frederick M. Gibson†: Several times during the session the statement has been made that a manufacturer can secure a better return on his money by purchasing power and putting his money into production than can be secured by investing his money in an isolated power plant. This may be true in some cases, but not in all. From statements made by other engineers, it seems to be the consensus of opinion that production is limited more often by the amount of sales than by the production capacity of the plant. I think that Mr. Warren stated it in a new way when he said that a certain saving in the cost of power would amount to 15 per cent of the profits of the company.

With regard to higher steam pressures, I am not prepared to go into the technical end of the discussion. It might be well to look beyond the power plant to see what possible benefits could be derived from higher steam pressures in a great many industrial plants that have a large demand for process steam. While this type of plant may not form a large proportion of the total number of plants, the amount of fuel that they consume is enormous. One plant alone is using over a thousand tons of coal a day, which is comparable with many of our large central stations.

When many of these plants were designed, it was customary to have a system of 125 lbs. pressure for live steam for the prime movers, a system of 60 to 80 lbs. for process work, and a system of 5 to 15 lbs. for heating. The prime movers exhausted into the heating pressure system. Pumps and auxiliaries throughout the plant used the process pressure system as live steam and exhausted into the heating pressure system. The "high pressure" system ran only from the boiler house to the power house, but the process pressure and heating pressure systems ran parallel throughout the entire plant.

In many plants the balancing of these systems has become very difficult. Improved processes are more economical in the use of steam, but generally require more power. The power load has been greatly increased by the introduction of automatic machinery and the mechanical handling of materials. In order to reduce the production of exhaust steam

*Stone & Webster, Inc., Boston, Mass.

†Plant Engineer, American Sugar Refining Co., Boston, Mass.

the "high pressure" steam has been raised from 200 to 250 lbs. pressure. Steam-driven pumps and auxiliaries have been motorized. Efforts to use more exhaust steam have resulted in greater heating surfaces so that preliminary heating could be done by exhaust steam. In some cases banks of coils were divided, with one section using the heating pressure system and one section using process pressure system. In some cases individual heating coils had a double connection so that either system can be used. Such systems result in expensive complications, and in many cases they have not met the situation. In some plants, certain departments can operate only at certain scheduled periods in order to avoid overloading the heating pressure system.

I believe that there is a great possibility in many plants of doing away with the heating pressure system by using the higher steam pressures for the prime movers and by using high back pressure turbines to exhaust into the process pressure system. It would result in the simplicity of having one steam pressure system throughout the plant instead of two, the economy of smaller pipe sizes, decreased heating surface or increased production in apparatus using heating surfaces, and in greater flexibility in the operation of individual departments in the plant. The increased cost in the power plant might easily be justified by the benefits secured in other departments in the plant.

Mr. H. T. Chandler*: I am particularly interested in what Mr. Pope said about bleeding the receiver of a compound engine. One of the questions I would like to ask is, supposing he had an engine of, say, 175 lbs. steam pressure, initial pressure of ordinary proportions, about what would be the limits of the intermediate pressure that you could use for bleeding purposes?

And also Mr. Gibson's remark just now. I was wondering if he used 80 lbs. of steam in one line how he would handle the heating line which calls for 10 lbs.; whether he would continue to use reducing valves to get from the 80 lbs. down to the 10, or whether possibly he would use some sort of intermediate power producing apparatus?

Mr. Gibson: Where multiple effect evaporators are used, it would be advisable to use a reducing valve. Where stock in process may be damaged by the high temperature of the steam, a limited amount of water controlled by a thermostat could be sprayed into the steam to reduce its temperature to the desired point.

Walter Dimant†: In connection with the problem of power and high-pressure steam I would say that we have installed and had in operation at our plant a 5000 kw. Allis-Chalmers straight non-condensing turbine. It is operating on 150 lbs. pressure at the throttle and was installed to use 225 lbs. in case it was desired to use a higher pressure ultimately, which we might do in the future in case we changed the type of our boilers. This machine exhausts at 25 lbs., and our whole worsted department is operating on this pressure. Some changes had to be made in the manufacturing equipment to accommodate the lower pressure. The slashers formerly operated at 100 lbs. pressure and are now operating very satisfactorily on 15 lbs. exhaust steam pressure, and could, I think, be operated on a less pressure. There are many other chances to reduce the manufacturing steam pressures in textile as well as other industries. This, to my mind, is as important as increasing the initial turbine pressures, and might in some cases produce a better manufactured product. If power is needed then it will probably be wiser to increase the turbine throttle pressure up to the point where sufficient power

*Plant Engineer, Walter Baker Co., Ltd., Dorchester, Mass.
†Superintendent of Power, Amoskeag Mfg. Co., Manchester, N. H.

can be derived from the steam passing through the machine. With a reduction in the exhaust pressure it will of course help this out materially. I don't think in any individual plant there is much need of increasing the pressure above that needed to give the desired power unless you can make use of the excess power.

There is another point to be brought out, and that is the use of the steam in case it is to be by-passed. Suppose the turbine should shut down for any reason and you have to pass all the manufactured steam used immediately through reducing valves to accommodate the manufacturing conditions. If you are operating at a high initial pressure combined with a high steam temperature, you are bound to have trouble with reducing valves, as not many will stand this condition for any length of time. In addition to this the temperature might cause considerable trouble to the manufactured product as well as to the manufacturing piping and equipment. This should be given very serious thought. Each plant, as Mr. Pope has said, has got to be considered by itself.

In some cases plants are entirely revamped in order to increase the steam pressures, obtain more power, etc. Very considerable thought should be given to this, for in every case, from an individual plant standpoint, it will resolve itself into a question of dollars and cents, which it should. In almost every case additional power can be obtained with a probable reduction of labor, but the question to be decided is whether, after all changes are made, the saving will be sufficient to cover the interest on the investment made, with some to spare. Let us all remember in the final analysis it is a question of what it will cost and what returns you will get.

PERCY C. IDELL*: We hold no brief for high-pressure boilers one way or the other, but it is interesting to us to see how the demand for them is increasing. We have about 400,000 hp. in use now for 350 lbs. or over, of which about 60,000 hp. is for 650 lbs. or over. We have on order one boiler for 1390 lbs.

Now, whether there is any efficiency in 1390 over 1200 lbs. I will leave to my good friends Mr. Pope and Mr. Moultrop to tell you.

Let us turn to the industrial plant, which I understand is the keynote of this meeting. For a number of years nationally known plants and companies, like the General Electric and Singer Manufacturing Company, have been buying boilers for about 250 lbs. Do not ask me why they buy them; that is for you engineers. I think it is quite interesting. They used to come to our office and say, "Well, now, what do you think about this high pressure? Do you think we ought to go to it?" Now they are coming in and saying, "We want 250"; "we want 350 lb. boilers."

Referring to the industries of New England, in the textile mills, we have a number of recent orders for 250 and 300 lb. boilers, and in paper plants we have recently received several orders for 300 lb. boilers. We have on order a 1200 lb. boiler for a fibre company out in Mississippi. I have not the least idea why they want that pressure. It is a secret process in some way, and they do not want the steam constantly, they want it in surges of three or four minute intervals.

We have in this city a 650 lb. boiler at the Manning, Maxwell & Moore shop for testing the high-pressure valve and fittings. That is a riveted drum, and it may be interesting to you to know that the 650 lbs. is considered about the limit of the riveted drum. That gives you a 2-inch plate, a 2-inch bow strap inside and out, and a 6-inch rivet, which is long enough.

MR. POPE: There is one question remaining unanswered, and that is about bleeding the receiver of reciprocating

*District Sales Manager, The Babcock & Wilcox Co., Boston, Mass.

engines. I have considered somewhat the problem of bleeding those engines, but I have never gone so far as to determine that it actually could be done. However, I do not see why it can't be done. It seems to me that one can automatically control the cutoff on the low-pressure cylinder, to keep any normal receiver pressure, which I presume is from 5 to 15 lbs., and bleed any quantity within the usual limits. You can't take all the steam out of a bleeder machine, whether it is a turbine or an engine; you have to let something go through to the condenser, and if you want the maximum of power you can't take any out. You have to work between the limits of a lot of steam and a little power, and a lot of power and a little steam. I should think the particular question could best be answered by the manufacturer of the engine, and I would be glad to hear what he felt he could do about it.

I have not anything in particular to say in closing excepting that I do not want anybody to think that I am knocking high-pressure steam, or that I condemn it, because—far from it—I do not. I simply have been asked to talk on the advantages and disadvantages.

There is only one advantage to high-pressure steam, and that is that it may enable you to get more power with the same weight of steam; everything else about it is a disadvantage, as I think all will admit.

Utilization of Extraction Steam

By E. D. Dickinson, A. D. Somes, and R. G. Standerwick

PART 1

By Edgar D. Dickinson

Designing Engineer, Turbine Engineering Department, General Electric Company, West Lynn, Mass.

Some years ago I heard a statement made to the effect that before long we would see no more small turbines being installed, for the reason that it would be found uneconomical to generate electric power in small power stations. It is true that the large stations have made such improvements in efficiency that they are able to produce a kilowatt-hour at a figure far below what might be expected in any industrial plant, and if we consider the cost of electric power alone, the statement would be justified. However, we find that an increased number of the smaller turbines are being sold and at the same time there is a marked tendency toward increased capacity.

Engineers are constantly striving for greater economies, and in analyzing the costs in any manufacturing industry the charges that have to be allowed for heat and power must be given the same consideration as those for labor and materials. Therefore the engineer is always on the lookout for means whereby these two items can be reduced.

In the early days of the steam turbine it was recognized that a certain amount of power could be produced at relatively low cost by the use of low-pressure or mixed-pressure turbines, and a number of this type were installed with very gratifying results. As power plants developed and an increased number of condensing turbines were installed, the amount of low-pressure steam available to be transformed into useful work was reduced. This accounts for the decreased use of the mixed-pressure turbine.

Further studies of manufacturing processes showed that in many instances large amounts of steam were being generated only to be used at a lower pressure after passing through reducing valves. It was apparent that a great deal of heat energy was being wasted that might be converted into electricity by the simple expedient of using a steam turbine as a reducing valve. With the more general use of higher pressures and temperatures the amount of power that can be so generated is very much increased. We now find that wherever consideration is being given to remodeling or increasing existing power plants, very serious consideration is being given to the installation of high-pressure boilers fitted with superheaters, and a most careful study is being made of the heat balance to be obtained in power houses in conjunction with the manufacturing processes.

Extraction-Type Turbines

In many instances where sufficient power cannot be generated by the non-condensing turbine it has been found desirable to use turbines arranged for bleeding the requisite amount of steam from one or more of the stages. These we call the extraction-type turbines.

In its simplest form, any turbine provided with an opening in the shell

might be classed as an extraction turbine. In such it will be apparent that inasmuch as the stage pressure will fluctuate with the opening of the primary valves in response to the governor, the steam available for extraction will vary with the load. This type of extraction can be commended on the score of simplicity, and for applications where the relation between steam demand and load is approximately constant, this type of turbine is admirably suited. This means it is most generally employed for providing steam for feed-water heating, and the necessary control is reduced to the minimum, as both the extracted steam and the flow to throttle will be approximately proportional to the electrical load. Control of pressure can be obtained up to the stage pressure by the introduction of a reducing valve in the extraction line.

There are two means generally employed for controlling the pressure in the stage from which steam is to be extracted. The one first developed and still used in many cases is to fit one or more blank diaphragms in the turbine, which to all intents and purposes divide the turbine into several turbines. In such machines the steam is all extracted, and what is not required for process is admitted through a suitable valve into the lower pressure stages. The other method is to provide a suitable valve in the diaphragm following the stage from which steam is to be extracted. The valve is arranged to close or open the nozzle ports and maintain the proper pressure in the extraction stage. This is commonly called grid-valve extraction. This method allows maximum efficiency to be obtained in an extraction type turbine and is particularly valuable in turbines where the steam is to be extracted at moderate pressures where the specific volume is great. Losses inherent to deflecting all of the steam from its path and the pressure-drop losses due to carrying the steam through tortuous passages are avoided.

In some processes it has been found desirable, in order that maximum plant efficiency be obtained, to use steam at several different temperatures and pressures. This is done by extracting steam from several stages.

No general statement can be made as to the relative merits of the various types of extraction turbines. A thorough study of the heat and load cycle per day, week, and year is necessary before recommendation can be made. In some instances where there are wide fluctuations in relative demands for electrical power and heat it has been found best to install both condensing and noncondensing turbines and reducing valves all designed to have similar characteristics, so that good regulation of both speed and pressure can be obtained. There are other instances where it has been found desirable to fit turbines with reducing-valve extraction in the upper stages and grid-valve extraction in the lower stages.

Whether one buys or generates electric power is entirely an economic question. In manufacturing plants where the electrical demand is relatively high and the steam demand small, it will probably be more economical to purchase power than to generate it.

In controlling extraction-steam pressure on extraction-type turbines, many problems in governing are met with which are not encountered in straight condensing turbines. The governing mechanism must be extremely powerful, and every precaution taken to reduce to minimum hunting or swinging of the load and pressure. In industrial plants the turbines are often subjected to rapid and severe changes in load and demand for process. The load swings are relatively greater than encountered on big systems, where the turbines operate at approximately constant load.

The kilowatt rating of a machine is no criterion of the capacity of the inlet valves or of the control demands that must be met by the governor. An extraction-type turbine of 5000 kw. rated capacity may have a steam flow equal

to a 20,000 kw. condensing turbine. The demand for extraction steam may be continuously changing through a very wide range. The control mechanism must automatically maintain extraction pressure within commercial limits without change of the speed governor.

It is sometimes economical to arrange the extraction-type turbine so that during periods in the manufacturing cycle, low-pressure steam may be admitted to the extraction stage and used to generate electric power. Such turbines as this, of the mixed-pressure type, serve a most useful and valuable purpose in maintaining approximately constant pressure and preventing waste in systems where an excess of low-pressure steam cannot be avoided during certain periods.

A word on the subject of efficiency might be pertinent. We hear some talk in a general way of the high efficiencies that are being secured on this or that particular turbine. The highest that I have seen quoted on a non-condensing turbine was that of a Brunner turbine. This was rated at 3000 kw., and with 182 lbs. gauge pressure and 740 degrees steam temperature it showed a Rankine efficiency of approximately 84 per cent. This means about 78 per cent over-all efficiency with 200 lbs. and 100 degrees superheat and including generators. It is my understanding that this turbine was built in two casings and had some forty stages. It is altogether probable that the efficiencies reported were realized. However, the capitalized value of the saving that might be secured by such a turbine would not be warranted with the present price of fuel. On the other hand, turbines having efficiencies only a few per cent lower are well justified. It must be borne in mind that these figures are all relative and considered as applying to average sizes of turbines generally used in industrial plants. Efficiency is not a general term. To be intelligently considered, we must specify all conditions, viz.: capacity of turbine, pressure, superheat, and back pressure. For the larger turbines used in the big power houses entirely different conditions exist, and these must be given special consideration.

The design of the extraction and mixed-pressure turbine is considerably more complex, and takes a great deal more time than the straight-condensing or non-condensing turbine. In discussing efficiencies one must always realize that the mixed-pressure or extraction-type turbine is a compromise. Every turbine is laid out to have the proper steam velocities at one load. It will be apparent, therefore, that at all other loads the steam velocity will not bear the proper relation to the bucket velocity, and as a consequence there will be some sacrifice in efficiency.

In the extraction-type turbine the high-pressure end must be designed to carry not only the steam required for extraction, but, in addition, the steam which will pass through the low-pressure stages to the condenser. Therefore, when such a turbine is operated straight condensing and with the same electrical load, the steam flows through both high and low pressure parts of turbine will be different, and in consequence the efficiency will be affected. Speaking generally, in an extraction type turbine the high-pressure end is relatively larger than would be for straight condensing, and in a mixed-pressure type turbine the low-pressure end is relatively larger.

The following may be of interest. We have on order and in commercial operation, in sizes from 500 to 3000 kw., approximately 300 of the non-condensing turbines, 200 arranged for reducing-valve extraction and 300 arranged for grid-valve extraction, making a total of 800.

As an index of the increasing demand for turbines where steam is to be used in manufacturing processes, 65 per cent of recent orders in sizes from 1500 kw. to 6000 kw. have been either non-condensing or arranged for extraction.

Utilization of Extraction Steam

PART 2

By Arthur D. Somes

Turbine Engineering Department, General Electric Company, West Lynn, Mass.

Few industrial power plants exist for the production of power only. Heat is required in many industrial processes, and the production of heat for process work is a very important purpose of such power plants. Where economical power can be purchased, their only purpose may be the production of heat for process work, which can seldom be purchased economically. Since steam is a medium very commonly used for supplying large quantities of controlled heat, these plants must have equipment for producing and distributing large flows of process steam, as well as power.

This paper is a discussion of the ways in which various types of steam turbines may be applied to the economical production of power and process steam for industrial processes. No attempt is being made to show what will be the most economical type for any particular plant, but rather a review of the types that have been tried and proven practical in actual applications.

The most economical industrial power plant is the one that produces the needed power and process steam at the lowest cost. In general, the highest efficiency in power production is obtained when all process steam is supplied at the lowest possible pressure at which that process can be advantageously carried on, and as much energy is absorbed from the process steam in expanding through the stages of a steam turbine from boiler pressure to process pressure as practical limitations will allow. To the process, the turbine functions as a reducing valve with the advantage that it develops useful power. The characteristics of the turbine have little effect on the over-all economy of a plant in which the power available from the process steam is in excess of the power requirements of the plant. When, however, the power demand exceeds that generated by the process steam, the deficiency must be purchased or generated in a condensing turbine with an unavoidable loss of heat to the cooling water. High economy in generating power from process steam is essential to high over-all economy.

Types of Turbines

The various types of steam turbines that have been developed and that are now available for generating power from process steam are given in the table below. An automatic extraction turbine is one so built that any amount of steam from nothing up to the capacity of the high pressure section may be extracted at a given pressure. Ratings range from 500 to 10,000 kw.

The types of turbines are:

1. Straight non-condensing for high and low back pressures.
2. Non-condensing single automatic extraction.
3. Straight condensing with from one to three bleeder points for feed heating.
4. Condensing single automatic extraction or mixed pressure.

5. Condensing double automatic extraction or mixed pressure.
6. Low-vacuum heater turbine exhausting into a condenser heater with or without single or double automatic extraction.
7. Extraction turbine, extracting through reducing valves or into dead-end heating systems.

These units can be applied successfully in such industries as:

1. Paper.
2. Textiles.
3. Metallurgical.
4. Sugar.
5. Lumber.
6. Chemical products.

The non-condensing turbine can be applied to best advantage where large flows of process steam are required without large fluctuations in flow. Under these conditions high efficiencies may be obtained. Equipped with a back-pressure regulator it must be operated in parallel with existing equipment. This combination is equivalent to a condensing automatic-extraction unit. Without back-pressure control it must operate in parallel with reducing valves from the boiler, or in some cases with a condensing automatic-extraction mixed-pressure turbine.

The non-condensing automatic extraction turbine is equivalent to two non-condensing units operating in parallel at two different back pressures, with the advantage of a mechanical speed connection between the two, instead of an electrical connection. It has the efficiency and operating characteristics of the straight non-condensing turbine.

The condensing automatic-extraction turbine is equivalent to a non-condensing turbine operating in parallel with a condensing turbine with a mechanical speed connection between the two. It does not have the high economy features of either the straight non-condensing or condensing machine. It is, however, capable of handling wide fluctuations in load and process-steam flow with good economy. Being a single unit and self contained, it has lower losses and requires less floor space.

The condensing double automatic-extraction turbine is equivalent to two non-condensing turbines with different back pressures, or a non-condensing extraction turbine operating in parallel with a straight condensing unit. It has the efficiency and operating characteristics of the condensing single automatic extraction machine.

The low-vacuum heater turbine exhausting into a condenser heater can be applied to good advantage in plants where large quantities of cold water must be heated continuously. The water can be heated in one, two, or three stages of heating, with all of the advantages of the regenerative feed-heating cycle that is now so generally used with large condensing units.

The extraction turbine extracting steam through reducing valves may prove economical where very small amounts of process steam are required. The amount that can be extracted at any given pressure is limited by the decreasing pressure in the turbine stage with decreasing flow to condenser. With large extractions the throttling of the steam from the stage pressure to the process pressure at some loads represents a large loss in available power.

Typical Installation

Now, these types of machines may be used in various combinations to meet the most complicated demands for process steam. As an example of how these combinations have been worked out for particular plants, the following description of an application to a metallurgical process is typical.

In this case the power requirements remain at two definite values, without any great variation, the first at 5500 kw. and the second at 9800 kw. High-pressure steam is generated at 365 lbs. and 200° superheat. There is available from low-pressure waste-heat boilers

saturated steam at 165 lbs. pressure. The quantity of steam generated from these waste-heat boilers varies over a wide range.

There is a large variable demand for process steam at 6 lbs. absolute, 2 lbs. gauge, and 165 lbs. gauge, and a small demand at 30 lbs. gauge. All of the steam used for process work is contaminated and lost, which means that the bulk of the boiler feed water is taken into the plant at a temperature between 40° and 60° F.

To meet these conditions, a combination of three turbines driving a.c. generators proved the most economical. The first is a 3000 kw. low-vacuum unit exhausting to the 6 lbs. absolute process, with automatic extraction of process steam at 2 lbs. gauge. Steam will be extracted from this unit for extreme or emergency conditions only. The second and third, which are identical, are 5000 kw. condensing machines operating at a vacuum of 28½ inches of mercury. Each turbine is designed for automatic-extraction or mixed-pressure operation at 165 lbs. gauge and automatic extraction at 2 lbs. gauge, with provision for bleeding steam at 30 lbs. gauge from an intermediate stage through a reducing valve or into a dead-end heating system. The mixed pressure feature operates to use up the excess low-pressure steam during the periods when the process requirements at 165 lbs. gauge are less than the output of the waste-heat boilers.

In addition to the process steam, the boiler feed water, which includes approximately 100,000 lbs. per hour of cold water, is heated in three stages by extraction from the turbines along the lines of the so-called regenerative feed-heating cycle.

At the 5500 kw. load point, the 3000 kw. unit and one 5000 kw. unit are operated. At the 9800 kw. load point all three units are operated.

At the 5500 kw. load point a kilowatt-hour is produced with a heat consumption chargeable to power of 4430 B.t.u. At this condition the flow to condenser is little more than enough to cool the low-pressure end of the turbine. At the 9800 kw. load point a kilowatt-hour is produced with a heat consumption chargeable to power of 8750 B.t.u. The increased heat consumption at this load is caused by the greater flow to condenser due to the fact that the process demands do not increase with the increased load.

Heat must be produced to carry out the processes, and the necessary power is obtained with a low additional heat consumption per unit of output.

Utilization of Extraction Steam

PART 3

By Reginald G. Standerwick

Turbine Engineering Department, General Electric Company, West Lynn, Mass.

This paper deals with the methods of regulating flow of steam through turbines, with particular reference to extraction and mixed-pressure applications. The descriptions given apply to the General Electric Company's 3600 r.p.m. units.

The usual speed-regulating governor consists of a simple spring-loaded fly-ball governor driven from the main shaft by means of a worm gear at approximately one-sixth of the turbine speed. This governor has a possible speed range of from about 500 to 750 r.p.m. and a tolerably straight line characteristic between these extreme points. The governor is so arranged that the speed may be changed over a wide range by hand or by the synchronizing motor while the unit is in operation. This governor controls the flow of high-pressure steam to the turbine, and is employed in the full line of turbines which is being built at the present time, whether they are for straight condensing operation or to be used for extraction purposes, so that the machine is always protected against over-speeding by this mechanism or some slight modification of it.

In addition to this speed-control mechanism, there is, of course, the emergency governor, which, if the turbine should, by any possible accident to the governor, exceed the speed at which this control mechanism is supposed to work, will limit its speed and entirely shut the steam off after an increase of 10 per cent of normal speed value has been reached. This governor is a simple bolt-type emergency governor mounted directly on the main shaft of the turbine, whose action is to immediately close a quick-closing valve.

The next in order will be the simplest form of turbine from which low-pressure steam is obtained, i.e., the single or multi-stage back-pressure turbine. Such turbines receive steam from the boilers, and, after utilizing as much energy as is available, exhaust steam at anywhere from 1 to 200 lbs. pressure. The pressure in the exhaust casing may be held essentially constant by the use of a back-pressure regulator. This regulator is, in general, in the form of a diaphragm spring-loaded, upon one side of which the pressure of the exhaust casing is applied, moving an electric switch which operates the synchronizing motor, thus changing the relation of the valve opening to the position of the governor. It is, of course, essential that machines so regulated be caused to drive an a.c. generator which is synchronizing onto a system which is at least twice as large as the capacity of this machine, the rest of the system maintaining the frequency. In this way the high-pressure valves may be opened and closed by the synchronizing motor and essentially constant pressure maintained in the exhaust.

A typical curve is here shown (Fig. 1), the lower portion of which shows the effect obtained when operating with hand regulation, and the upper portion with automatic back-pressure

regulation of the turbine. This was taken in a large industrial plant.

Next to the straight back pressure machines, in the order of simplicity, would be machines which may be condensing or non-condensing, but from which steam may be extracted from one or more stages without the use of any regulating mechanism within the turbine other than the speed control which we have described. When steam is so bled, it is either taken at whatever pressure the stage pressure happens to be, or is reduced to some lower pressure by means of a suitable reducing valve. Great care has to be exercised in the selection of reducing valves which are expected to work in conjunction with the regulating devices of a turbine, and, in some cases, it has been necessary to design reducing valves for the particular requirement.

Then there are those machines which are automatically pressure regulated and which are connected to a condenser. Here the steam at various pressures may be extracted from various stages of the turbine. The pressure is regulated by the opening and closing of a valve which is interposed between the extraction stage and the following stage. This valve takes the form of a grid which is opened or closed by an operating cylinder in response to the variations in pressure in the extraction stage. As this valve gradually closes under the action of the piston and operating mechanism, the flow to the condenser is reduced either to take care of a condition of constant extraction with reducing load or of increased extraction with a constant load.

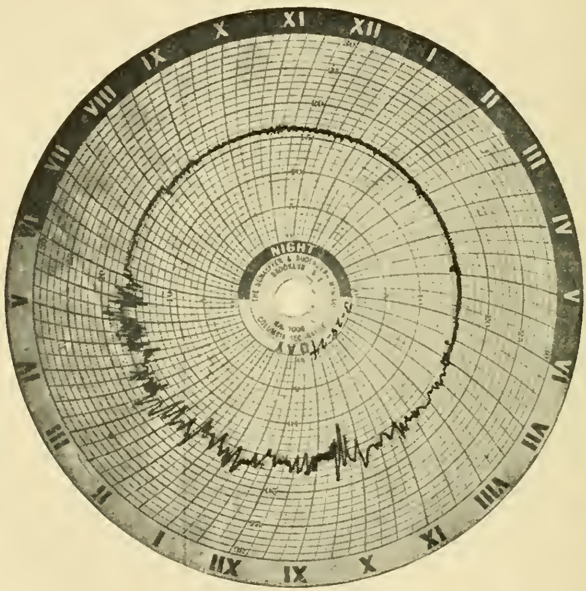

Fig. 1—Comparison of Hand and Automatic Pressure Regulation on 3000 Kw. Back Pressure Turbine

This closing of the grid is accomplished by the action of the operating cylinder, which is steam actuated and is of the double-acting type. The position of the piston of this operating cylinder is determined by the position of the diaphragm, on one side of which the pressure from the extraction stage is applied. The other side of the diaphragm is spring loaded with an adjust-

able hand wheel to vary the pressure. As with the speed governor which has been described, restoring or stabilizing mechanism is used with this operating cylinder to prevent over-travel (Fig. 2). The hand wheel may be replaced by mechanism operated by a small motor for control of extraction pressure at a remote point. It is, of course, in this case not necessary to have the generator of this turbine synchronized to the system because varying loads may be carried at will, the balance of the steam not required by the extraction line being passed to the condenser automatically, load changes of as much as 30 per cent are made suddenly, there is no appreciable disturbance. Steam may be extracted in this order of turbine at any pressure from 1 or 2 lbs. up to as high as 200 lbs.

There are occasions when it may be detrimental to have even slight disturbances in speed of the unit due to changes in extraction steam demand, or variations in pressure due to change in electrical load demand; and to overcome these objections, what is known as the triple-crank mechanism has been developed. In this way it is possible not only

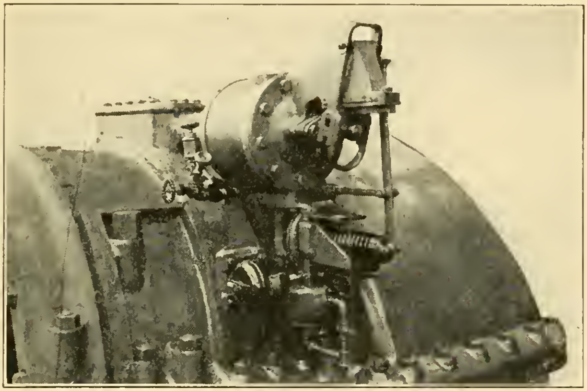

Fig. 2—Automatic Extraction Device Equipped with Remote Control for Curtis Steam Turbine Sets

which is not, of course, possible in the case of straight back pressure units.

Figures 3 and 4 show the results obtained from such a mechanism. The first curve shows pressure regulation obtained by hand-reducing valve operation, and the latter the improvement obtained when the automatic mechanism was installed. This type of control is known usually as a simple-extraction mechanism.

There is no attempt made in this mechanism to prevent slight disturbances in the frequency of the turbine due to varying extraction demand or of the pressure of the extraction stage due to variation in electrical load demand. As will be seen from the various slight disturbances on the pressure chart where to move the grid valve at the extraction stage so as to regulate the pressure of the extraction line, but at the same instant to move the high-pressure valve in an opposite direction to that of the grid valve. By so doing, it is possible to so adjust the opening of the high-pressure valve and the grid valve as to maintain the pressure in the extraction stage with a change in extraction steam demand without changing the total energy imparted to the turbine. Very large variations in steam demand at the extraction point can be taken care of with essentially no change in speed of the turbine. The mechanism will adjust itself so that, upon changes in electrical load demand, the extraction pressure is but very little affected.

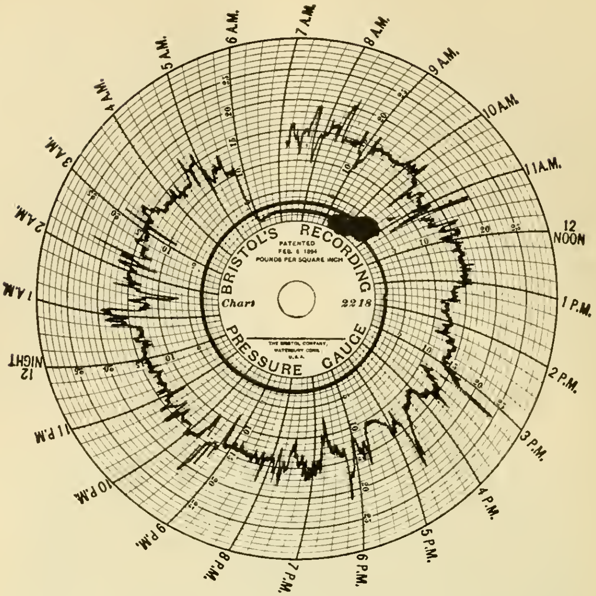

Fig. 3—Extraction Pressure—Hand Control Extraction

This mechanism will also permit of mixed-pressure operation, which is, of course, of extreme value where excess low-pressure steam, over that required by the industrial plant, is available. The turbine will automatically operate on a maximum quantity of excess low-pressure steam where such is available, economiz-

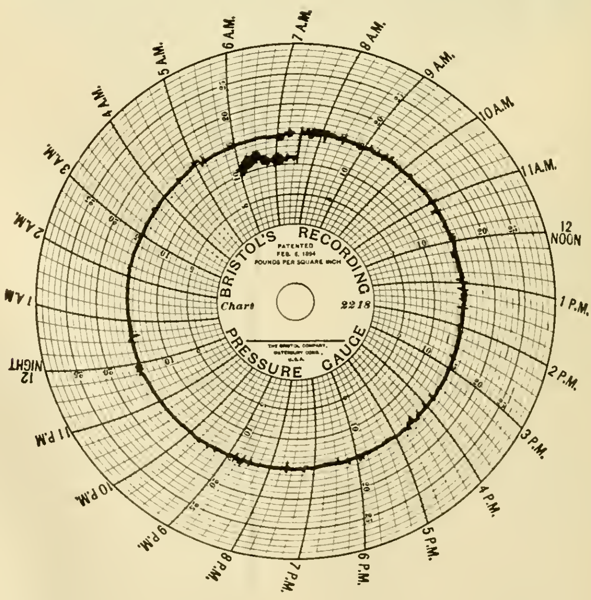

Fig. 4—Extraction Pressure—Simple Automatic Extraction

ing on the high-pressure steam, but will automatically maintain essentially constant speed if the excess low-pressure steam diminishes, by utilizing high-pressure steam in place of it. The quantity of excess steam, of course, is determined by an increase in pressure in the extraction line over that at which the turbine mechanism was adjusted to extract. With the form of mechanism used on the more recent designs, it is possible to make adjustments to get the very finest pressure and speed regulation obtainable after the machine has been installed in the customer's plant. This could not be obtained with some of the earlier types.

Probably the latest regulating mechanism on a turbine is that which not only has to maintain essentially constant speed, but also essentially constant pressure in more than one stage of the turbine. In accomplishing this two grid valves are assembled in the turbine. Here steam may be extracted at two widely varying pressures, say 100 lbs. from an early stage and 10 lbs. from a later stage, the remainder of the steam passing off to the condenser. In this case the control could be either by steam extraction where each of the grid valves is moved independently by its own pressure-regulating mechanism, or the two grid valves and the speed governor may have to be interlocked so that the variation in steam demand from either of the extraction points may be varied without disturbing the pressure in the other one and without disturbing the frequency of the machine; or the electrical load may be changed without disturbing the pressure in either of the extraction stages. To accomplish this, much more intricate mechanisms are necessary.

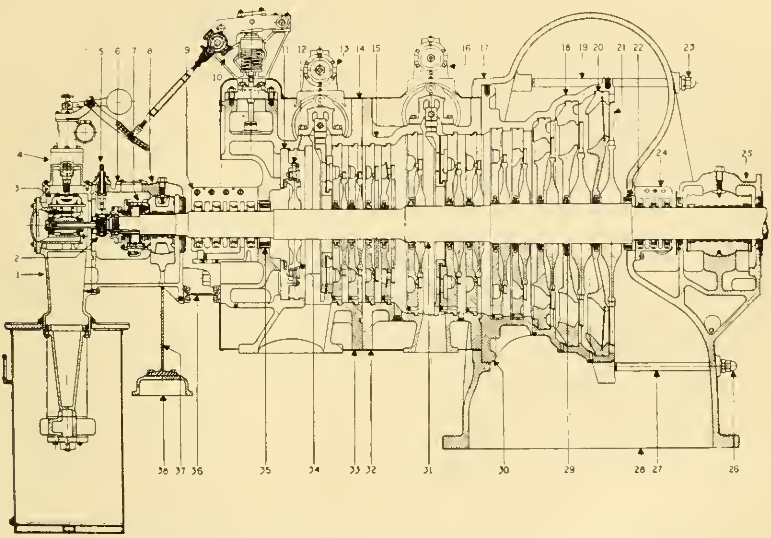

Fig. 5—Condensing Type Curtis Steam Turbine with Two Points of Automatic Extraction

In laying out an industrial plant in which extraction steam has to be used, it is very necessary that careful consideration be given to the types of steam-reducing valves if they are to be used in conjunction with the automatic devices of the turbine. It has been found necessary in some instances for us to design and build our own power-operated pressure-regulating valves so that interference between the reducing valve and the turbine mechanism will not occur. Valves of this kind have been built with

the pressure diaphragms spring-loaded operating a pilot valve of the operating cylinder which moves the regulating valve. In some installations it has been necessary to provide a magnetic device to put the reducing valve automatically out of operation, or into operation upon the accidental disconnecting of the back-pressure turbine from the system. It is very essential for those having charge of the layout of systems to be sure to study the action of the various regulating devices in order to steer clear of what may be very serious interference.

Besides having to regulate these turbines as extraction machines, we have also to be able to vary their speed over very wide ranges for such things as variation of frequency of system of sugar mills, water-works pumps, or even turbine-driven vessels. Many turbines have been built in which the speed may be varied from as low as one-sixth speed to full speed, the unit being able to carry at any of the speeds from no load to maximum load with the same relative change in speed. Even in this case the standard speed governor is not dispensed with, but acts in case of over-speeding of the turbine as a pre-emergency.

Besides being required to vary the speed of turbines over wide ranges, it is sometimes important on a straight speed-governing device to obtain an absolutely constant speed over full power range of the turbine. This is accomplished in a mechanism, which, while being inherently stable and, therefore, having a certain small degree of width, becomes, after a short interval of time, absolutely isochronous. Thus its speed is maintained essentially constant, irrespective of the load.

There are also cases where it is required to hold pressure constant within very small limits. Such mechanisms have been built which maintain a stage pressure essentially constant with very wide ranges in steam demand. This pressure-regulating mechanism, while being inherently stable and having width, as any other pressure-governing device, in a short interval of time becomes isodynamic.

There are many other forms of regulating mechanism for different purposes, such as, for example, used for the control of turbine-driven compressors, where constant volume, constant suction, or constant pressure may be maintained on the intake or the discharge of the compressor by controlling the speed of the turbine. Such control mechanisms regulate within very fine limits.

Conclusion

In conclusion, we wish to emphasize the point that narrow pressure or speed regulations are not merely dependent upon the design of the governing mechanism. While it is possible to design the power and speed of the high-pressure valve mechanism to respond satisfactorily to the maximum possible speed variations in the turbine which are limited by the WR^2 and rotation losses of the unit, yet when it comes to pressure control, the equivalent stabilizing factors are the capacity of the extraction steam lines, and the rate at which the demand of steam is changed. Under certain conditions it is possible to use slow types of control mechanisms for pressure control. Under other conditions it is necessary to use most highly sensitized types of direct-acting pressure governors. Even then it will be found necessary, in order to obtain stability of pressure in small capacity lines, to broaden relatively the pressure regulation in terms of varying extraction demands. Therefore, great care has to be exercised in deciding what type of regulating mechanism is required.

DISCUSSION

Ernest Pragst*: I should like to classify the industrial plants we have been discussing. It seems to me that we have been talking loosely about them, whereas a better understanding can be had if we divide them into characteristic groups, convenient to the engineer engaged in producing the power, steam, etc., required by them.

I think we can make two general classifications. The first will include those plants which need for use in their processes only power, and which must either purchase it or generate their requirements with fuel purchased solely for the purpose. It has been my experience that, in general, these plants can more economically purchase than generate their power where large central stations are present in the district to furnish it.

The second group will include those plants in which steam is used for process, or where it is available as a by-product of the industry, and those producing by-products which are available for steam generation. Only after a detailed study can one determine whether or not power should be purchased or generated for the plants of this group.

Now, this second group can be subdivided still further. We have the plants that use process steam at pressures well below boiler pressure. In them one can install non-condensing turbines when all exhaust can be used in process work, or extraction machines when the power required exceeds that which can be produced by the process steam. An alternative to this is the type of plants which use high-pressure steam for process and exhaust it at approximately atmospheric pressure, when it becomes available for power generation, by expansion through low or mixed pressure turbines. This is an uncommon condition, but I include it because I have met with one important installation of the type, which has been very successful. The case in question is a large locomotive manufacturing plant employing numerous steam hammers. There is produced from this exhaust steam 3000 kw. A second subdivision under this group includes those plants where by-product fuel is available for power generation. Typical examples of industries of this class are lumber and steel. In the former we have an excess of waste wood, and in the latter, blast-furnace gas. A third subdivision will include such plants as smelters and cement mills where waste heat is available for power generation.

W. G. Starkweather†: Years ago we started in with compound engines, and bled the receivers, and there was a control valve which took care of the regulation; then came the low-pressure turbine, and the whole story seemed to be low-pressure turbines, and we put in a lot of them and they worked successfully, but they did not fill the entire bill. Then the great General Electric and Westinghouse Companies brought out their mixed pressure, and mixed flow turbines, and today these turbines should be called the "universal" because you can do most anything with them—extract low pressure, add low pressure, draw off at any stage you want, or both. They are marvelous machines.

The question arises whether, with all this intricate mechanical design, these wonderful applications of mechanics, with mercury columns to control oil pressures, pilot valves, springs, oil levels to be maintained, etc., the operating man is up to it, and whether he can utilize the facilities that the General Electric and the Westinghouse Companies offer for application to his needs. Personally I do not think the usual operating men are quite up to it. I know of cases where mixed pressure turbines have been put in, and not used as intended;—where extraction turbines have been put in and no steam ex-

*General Electric Co., Schenectady, N. Y.
†Starkweather & Broadhurst, Inc., Boston, Mass.

tracted, and they say it is the fault of the operating man. So it is, but primarily he was not up to it. Now, whether he can be educated up to it is the question. I hope he can be. He must be, of course, if he is going to maintain his standing; but machines are not growing any simpler.

Pell W. Foster, Jr.*: There is one point which has not been touched upon, and although it is not in my own field, I think it is a thing which should be considered. We discuss the ways and means of getting steam at a pressure which is suitable for use in process work. We have not discussed the question of getting the foreman in charge of that particular process to use lower pressure steam than he has been using for the last thirty years. Now, that might be classified, if we are classifying, as a psychological problem rather than an engineering problem. But I think that as manufacturers and as engineers in these mills we have got a problem right there. In other words, your dye-house superintendent has always used 100 lbs. pressure steam to make his dyes. They are the best in New England, unquestionably. But if you want to give him 25 lbs. pressure, everything is ruined. Now, I think you all have run into that —I know all salesmen have. The salesmen want to sell something which is most efficient for the customer, and the plant engineer is right with them, because he realizes the potential saving, but when you get down to the dye-house foreman he may not agree with you. There may be a lot to say on his side of the story, but after all it is an engineering problem. I do not know anything about dyes, and I probably never will. A lot of us do not. We all know this, though, that if we put a definite amount of B. t. u.'s into a given weight of water and dye for an hour, a certain temperature will result. Whether we put the heat in with a certain weight of low-pressure steam or a lesser weight of high-pressure steam, if we keep the B. t. u.'s constant, I think the cloth is going to be the same color when you get through with it.

At first thought this may seem a trivial point, but I think it is an important factor. It is up to the engineers in the mills, if they are going to improve the thermal efficiency in their plants, to educate the men who are in charge of the process somewhat along engineering lines.

I would like to tell an amusing incident along this line. I happened to be talking to a man in a textile mill about this question and he said it was hard to get the local dye-house superintendent to fall in with it. He put in a turbine and he gave his dye superintendent steam at 25 lb. pressure, when he had been in the habit of using 100 lb. pressure. Something went wrong with the dyes that day, and the superintendent would not forget it. He said either he was going to leave the company or have 100 lb. steam—that was all there was to it. The man in particular, as I understand it, is one of the best dye men in New England, and they would rather pay twice as much for the steam and give it to him the way he wanted it than to make a small saving and lose the man who was a master at that particular game. He had a pressure gauge on the line which showed the pressure of the steam he was getting. A valve man, however, can change the pressure gauge. This was done, and this dye house today is using 25 lb. pressure steam with good results. The pressure gauge still reads 100 lbs.

Mr. Dickinson: I would like to take one minute, if I may, to refer to Mr. Pope's most excellent paper, and to say that we would like to discuss the use of high-pressure steam but have confined ourselves to the general situation.

So far as turbine design is concerned, it is very costly to make a 1200 lb.

*New England District Manager, Power Specialty Co., Boston, Mass.

pressure turbine. It can be done. It is purely an economic question.

Referring to Mr. Starkweather's remarks, I am glad those points were raised, because I have no fear of the future at all—absolutely none. There are any number of operating engineers who can give us cards and spades on handling their machinery and showing us how things ought to be done, and the whole thing is, as Mr. Starkweather points out, a matter of co-operation. It is quite possible that there have been misapplications, and in any case where a turbine is not functioning as it should, it is 50-50 as to whether the adjustment is a little off, the operator is a little off, or the designer a whole lot off. It is a matter for mutual education, and that applies to the mechanics as well as to thermo-dynamics.

I want to make a plea for exact data. There is a whole lot of guess-work introduced into engineering. Exact data is always difficult to get in the development stage of any art, because the man who wants it does not know exactly what he wants and the man who is making it does not know exactly what it will do. The nearer we can come to getting facts, the better. We have numerous cases of special apparatus that have been an unqualified success from the first. We had the opportunity to do the necessary preliminary engineering for these, and the machines as finally designed and built differed quite materially from what was originally contemplated.

Referring to the last part of Mr. Pope's paper, we must always have in mind the economic side of the problem. As engineers we must guard against expenditures being made which will not return a proper interest on the investment. The interest may be anything you like. It may be dollars and cents or it may be safety. The installations under discussion are expensive and they are becoming more so. An increasing number of operating engineers are appreciating the gains in efficiency that are possible by going to the use of steam at higher temperatures and pressures. The equipment necessary for the use of high-temperature high-pressure steam is very much more costly than equipment for low-pressure saturated steam. The cost of every detail of equipment, as pointed out by Mr. Pope, is going up every day, and it is a very bad thing for any industry, and for the advancement of engineering, to have uneconomic installations.

I think it might be pertinent to express a thought which has occurred to me occasionally, and that is, that we engineers should bond ourselves together in the use of electricity. Electricity is being used to such an increasing extent, in so many and diversified ways, that it seems quite possible we will ultimately see some of the larger industries tie in with some of the public-service plants. In the larger industries the power plant has the same caliber of men, gets the same treatment, the same careful engineering study, and the same quality of management as the public-utility plant. One is about as reliable as the other. The consequence is that they can tie in, can interchange power, and can help to smooth out the load factor. When all is said and done, they realize that heat and electricity are the tools which we are using to work with. Electricity is the means used for transferring power.

Looking at it from that standpoint, I think we will find many cases in the future where there will be good co-operation between the industries and the big public utilities to the advantage of all.

The Supply of Industrial Power

By William Harrison Larkin, Jr.

Power Engineer, General Division, United States Rubber Co., New Haven, Conn.

This paper is a study of what is often the largest item of factory expense, that is, the power plant. It is an attempt to let light into a corner shrouded with mystery for the office man and something often considered too technical a matter for much factory supervision and control. The examination of an industrial power plant should be based on four principles, namely, the question of its suitability, the possibility of future enlargement, its proper and economical operation, and finally, the availability of correct and continuous operating data and cost figures.

If the power requirements are small, the modern internal-combustion engine or a motor driven by central-station electric power may best meet the needs of the factory. Should the heating load be considerable, the steam engine with available exhaust would probably be more economical. When there is a large demand for process steam, the modern high-back-pressure turbine, or perhaps the bleeder-type turbine, may prove best.

The question of suitable boilers and fuel is important. Hand-fired boilers operated at low ratings are usually inefficient and can be replaced to advantage by modern water-tube boilers operated at higher ratings and better efficiencies.

Coal purchased may be cheap, but if transportation is high it often proves to be comparatively expensive. In New England, for instance, the higher-priced and better grades of coal usually generate more steam per dollar than the cheaper grades. A comparatively low-priced high-volatile coal must be burned with much excess air, resulting in inefficient operation, in order that the smoke may not exceed limits allowed by law. The use of fuel oil and pulverized coal may have advantages. Whether or not either can be justified is a matter requiring careful study from the investment and operating standpoints.

A well-considered power-plant program must contemplate enlargement. Many industrial plants are poorly laid out, are piecemeal growths of many years where expediency for the moment was considered above all else. Such plants are often enough found with small boilers of different types, uneconomical steam engines scattered about, sometimes several complete power plants located in different corners of the factory yard with long steam mains and transmission. Consolidation and electrification in such cases will usually pay satisfactory returns on investment and substitute an economical plan for future operation and enlargement for a haphazard method of generating power.

The day of the old-fashioned engineer who knew very little of theory, and cared less, is long past. The cost of fuel is too high for indifferent or careless operation, and inefficiency has too great an effect on the cost of production to pass unnoticed.

No factory can afford to neglect careful supervision of labor, raw material, and expense, of which the power house often makes up the largest item. No power plant can be considered as operating economically unless attention is paid to the matter of proper combustion, excess air, stack temperatures, feedwater

treatment, feedwater heating, return of hot condensate, boiler-cleaning program, best point of rating, suitable refractories and furnace volume, economical transmission, proper lubrication, necessary operating records, and all the modern aids to continuous operation at the highest possible point of efficiency.

No power department is well operated which does not produce regular and understandable data on power operating efficiencies and costs that can be compared from month to month with records of similar plants. Operators should be made to realize that 60 per cent boiler efficiency is poor, that costs per thousand pounds of steam generated, per engine horsepower, or per kilowatt-hour will be carefully checked.

Operating Costs

Figures are shown in Tables 1 and 2 which give comparative unit costs carefully compiled for the year 1924 from several factory power plants located in different parts of the country. The selection was made to show plants of varied character and sizes. These tabulations indicate a cost of steam averaging around 38 cents per 1000 lb. for plants in the Middle West, 49 cents per 1000 lb. for plants in the New York district, and 57 cents per 1000 lb. in New England.

Engine power per horsepower-hour averages 2.19 cents for the Middle-Western group, 4.42 cents for the New York group, and 5.54 cents for the New England group. Generated electric power per kilowatt-hour averages 0.693 cents for the Middle-Western group, 2.81 cents for the New York group, and 2.78 cents for the New England group. Few plants have water power, and the cost runs from 0.66 cents per horsepower in one case to 2.255 cents in the other. Public-service electric power per kilowatt-hour averages 1.86 cents in the Western group, 2.73 cents in the New York group, and 2.61 in the New England group. Assuming that all the motive power is purchased from the public-service companies, and using the demand and energy rates which prevail in the districts mentioned, the cost per kilowatt-hour would be approximately 1.612 cents in the Western district, 3.023 cents in the New York district, and 2.695 cents in the New England district.

In all these cases the public-service unit costs are made up of the cost per kilowatt-hour at the bus plus an operating charge which averages around 33 per cent. This operating expense covers the charges on the investment, operators' wages, and repairs and maintenance of substation, feeders, and motors.

Table 3 shows the method used in arriving at the comparative figures used in the tabulations. The object in presenting these figures is to give those who have the problem of power costs under consideration a picture of what is being done in plants of varying capacity and character, and to present a method by which definite conclusions may be arrived at.

Economy of Operation

Careful supervision over productive labor, the goods turned out by the factory, and the general matter of expense are usual and understood. Unfortunately, the matter of power-plant supervision is often considered too technical for control except in a very general way. The operating engineer receives very little attention in many industries, and indifference, poor operating efficiency, and high costs often result. Many smaller power plants run along in ways that were obsolete years since, and many factories with fine buildings and excellent machinery shelter power plants with scaled-up boilers, tubes covered with soot, leaky furnaces, broken baffles, engines with valve gear out of adjustment, hot returns thrown overboard, and similar losses which run on because of the lack of a little understanding and supervision from the office. No modern factory can afford to be without the instruments which indicate

Table 1.—Industrial Power Data

Group		Location	Average No. Employees Prod. & Non Prod.	Kind of Power Used	Annual Total Equivalent K.W. Hours	Total Cost Power (Boilers Not Included)	Cost Per Equivalent K.W. Hour	Estimated Cost All On Pub. Service Power
Central Group								
	1.	Indiana	368	Engine 20% Wat. Pow. 14% Gen. Electric 66%	11,892,211	119,512.42	.01005	.01686
	2.	Ohio	1203	Engine 5% Pub. Serv. Elect. 95%	7,013,395	143,724.91	.0205	—
	3.	Illinois	381	Engine 19% Pub. Serv. Elect. 81%	2,876,500	75,522.96	.02625	—
	4.	Michigan	3985	Engine 6% Gen. Elect. 66% Pub. Serv. Elect. 28%	33,530,767	380,524.72	.01136	.0145
	5.	Indiana	1032	Engine 23% Pub. Serv. Elect. 77%	5,155,372	94,096.23	.01825	.017
	6.	Maryland	—	Gen. Electric 100%	11,491,000	38,725.00	—	—
	7.	Penn.	—	Gen. Electric 100%	8,518,000	44,464.00	—	—
	8.	Louisiana	—	Gen. Electric 100%	9,598,000	40,983.00	—	—
N. Y. City Group								
	9.	New Jersey	1368	Engine 3% Pub. Serv. Elect. 97%	8,019,000	227,695.20	.0284	—
	10.	Conn.	328	Engine 50% Gen. Elect. 3% Pub. Serv. Elect. 47%	10,143,078	185,217.65	.0183	.01785
	11.	New Jersey	343	Engine 31% Gen. Elect. 5% Pub. Serv. Elect. 64%	420,447	23,339.03	.0557	.0426
New England Group								
	12.	Mass.	1136	Engine 3% Pub. Serv. Elect. 97%	5,291,000	134,292.86	.0254	—
	13.	Conn.	300	Engine 41% Wat. Pow. 25% Gen. Elect. 13% Pub. Serv. 21%	1,697,466	54,488.67	.0321	.02668
	14.	R. I.	613	Engine 1% Pub. Serv. Elect. 99%	3,847,598	111,459.85	.029	—
	15.	R. I.	919	Engine 24% Pub. Serv. Elect. 76%	3,842,000	102,790.23	.0267	.0324
	16.	Mass.	3150	Engine 80% Pub. Serv. Elect. 20%	2,601,023	—	—	.0275
	17.	Mass.	285	Pub. Serv. Elect. 100%	49,338	2,077.00	.0421	.0421
	18.	Mass.	1050	Gen. Elect. 86% Pub. Serv. Elect. 14%	1,294,778	21,566.75	.0167	.022
	19.	Conn.	1543	Pub. Serv. Elect. 100%	11,663,000	208,809.17	.01792	—
	20.	R. I.	159	Engine 56% Gen. Elect. 4% Pub. Serv. Elect. 40%	1,071,778	31,279.92	.0182	.039
	21.	Mass.	3700	Pub. Serv. Elect. 100%	31,206,000	390,075.00	—	.0125
	22.	Mass.	—	Gen. Electric 100%	6,631,000	37,697.00	—	.01342

Note:

Next To Last Column — Cost Per Equivalent K.W. Hour Means Cost Of All Classes Of Power As At Present Divided By The Equivalent K.W. Hours.

Table 2—Industrial Power Data

Group		Location	Average No. Employees Prod. & Non Prod.	Kind Of Power Used	Unit Costs For Power 1924				
					Steam Per 1000 Pounds	Engine Power H. P. Hour	Generated Power K.W. Hour	Water Power H.P. Hour	Public* Service K.W. Hour
Central Group									
	1.	Indiana	368	Engine 20% Wat. Pow. 14% Gen. Electric 66%	.316	.0115	.00885	.0066	——
	2.	Ohio	1203	Engine 5% Pub. Serv. Elect. 95%	.327	.0417	——	——	.01922
	3.	Illinois	381	Engine 19% Pub. Serv. Elect. 81%	.4929	.03	——	——	.0229
	4.	Michigan	3985	Engine 6% Gen. Elect. 66% Pub. Serv. Elect. 28%	.378	.0111	.00994	——	.01453
	5.	Indiana	1032	Engine 23% Pub. Serv. Elect. 77%	.3843	.0153	——	——	.0177
	6.	Maryland	——	Gen. Electric 100%	——	——	.00437	——	——
	7.	Penn.	——	Gen. Electric 100%	——	——	.00622	——	——
	8.	Louisiana	——	Gen. Electric 100%	——	——	.00527	——	——
N. Y. City Group									
	9.	New Jersey	1368	Engine 3% Pub. Serv. Elect. 97%	.462	.0669	——	——	.0253
	10.	Conn.	328	Engine 50% Gen. Elect. 3% Pub. Serv. Elect. 47%	.398	.0143	.0392	——	.0162
	11.	New Jersey	343	Engine 31% Gen. Elect. 5% Pub. Serv. Elect. 64%	.609	.0515	.01695	——	.0403
New England Group									
	12.	Mass.	1136	Engine 3% Pub. Serv. Elect. 97%	.5940	.0644	——	——	.01755
	13.	Conn.	300	Engine 41% Wat. Pow. 25% Gen. Elect. 13% Pub. Serv. 21%	.5550	.0288	.025	.02255	.0272
	14.	R. I.	613	Engine 1% Pub. Serv. Elect. 99%	.5700	.126	——	——	.0264
	15.	R. I.	919	Engine 24% Pub. Serv. Elect. 76%	.5260	.0332	——	——	.0214
	16.	Mass.	3150	Engine 80% Pub. Serv. Elect. 20%	.685	——	.0287	——	.0284
	17.	Mass.	285	Pub. Serv. Elect. 100%	——	——	——	——	.0421
	18.	Mass.	1050	Gen. Elect. 86% Pub. Serv. Elect. 14%	.5707	——	.0368	——	.0331
	19.	Conn.	1543	Pub. Serv. Elect. 100%	.5741	——	——	——	.01792
	20.	R. I.	159	Engine 56% Gen. Elect. 4% Pub. Serv. Elect. 40%	.5420	.0246	.042	——	.0344
	21.	Mass.	3700	Pub. Serv. Elect. 100%	.532	——	——	——	.0125
	22.	Mass.	——	Gen. Electric 100%	——	——	.0067	——	——

* Unit Cost Of Public Service Power Includes Public Service Bills, Plant Operation, Repairs And Maintenance Of Apparatus, Feed Lines, Etc., Depreciation And Insurance Charges. Usually Equals Public Service Charge Plus 20 To 30% (Average).

TABLE 3—SHOWING METHOD USED IN COMPARING PRIVATE OPERATION WITH 100 PER CENT PURCHASED ELECTRIC POWER

Plant No. 11, N. J., 1924

	TOTAL COST	UNIT COST	TOTAL POWER USED	EQUIV. K.W. HOURS
ENGINE POWER	8'812.98	.0515	171'280	128'500
GENERATED ELECTRIC	3'680.52	.01695	21'669	21'669
PURCH. ELECT. POWER	10'899.53	.0403	270'278	270'278
WATER POWER	—	—	—	—
TOTAL	23'393.03	—	—	420'447
AVG. COST EQUIV. K.W. HR.	(AS OPERATING AT PRESENT)			.0557

Plant No. 15, R. I.

	TOTAL COST	UNIT COST	TOTAL POWER USED	EQUIV. K.W. HOURS
ENGINE POWER	40'010.23	.0332	1'203'384	904'000
GENERATED ELECTRIC	—	—	—	—
PURCH. ELECT. POWER	62'780.00	.0214	2'938'000	2'938'000
WATER POWER	—	—	—	—
TOTAL	102'790.00	—	—	3'842'000
AVG. COST EQUIV. K.W. HRS.	(AS OPERATING AT PRESENT)			.0267

BELOW ARE ESTIMATES BASED ON THE SUPPOSITION THAT ALL THE POWER IS TAKEN FROM THE PUBLIC SERVICE ELECTRIC COMPANY AT WHOLESALE RATES.

PLANT* 11 N. J. COMPARISON, ALL ON PUBLIC SERVICE.		
TOTAL EQUIV. K.W. HOURS		420'447
AVERAGE PER MONTH K.W. HOURS		35'037
AVERAGE LOAD @ 172 HOURS PER MONTH, K.W.		203
MAX. DEMAND ESTIM. 150% ± (300 K.W. = 400 H.P.)		400
DEMAND CHARGES		
200 H.P. @ 1.50	300.00	
200 H.P. @ 1.35	270.00	570.00
ENERGY CHARGE		
3000 K.W. HRS. @ .03	90.00	
7000 " " @ .02	140.00	
25037 " " @ .01	250.37	480.37
COAL CLAUSE 35'037 K.W. HRS. @ .00085		29.78
TOTAL COST FOR ONE MONTH (PUBLIC SERVICE BILL)		$1080.15
COST PER K.W. HR. (PUBLIC SERVICE BILL)		.0308
OPERATING CHARGE 38½%		.0118
TOTAL COST TO PLANT PER K.W. HOUR		.0426

PLANT* 15 R. I. COMPARISON, ALL ON PUBLIC SERVICE.		
TOTAL EQUIV. K.W. HOURS		3'842'000
AVERAGE PER MONTH K.W. HOURS		320'166
AVERAGE LOAD @ 172 HOURS PER MONTH, K.W.		1'860
MAX. DEMAND ESTIM. 150% ± K.W.		2'800
DEMAND CHARGES		
200 K.W. @ 2.00 =	400.00	
100 " @ 1.85 =	185.00	
200 " @ 1.75 =	350.00	
250 " @ 1.65 =	412.50	
250 " @ 1.55 =	387.50	
500 " @ 1.45 =	725.00	
500 " @ 1.35 =	675.00	
800 " @ 1.25 =	1000.00	4135.00
ENERGY CHARGE		
320'166 K.W. HOURS @ .012		3841.99
TOTAL COST FOR ONE MONTH (PUBLIC SERVICE BILL)		7976.99
COST PER K.W. HR. (PUBLIC SERVICE BILL)		.0249
OPERATING CHARGE 30%		.0075
TOTAL COST TO PLANT PER K.W. HOUR		.0324

what is going on in the power plant and which will turn their messages of character of daily operation into the office continuously. There will be financial loss if the stack temperatures, excess air, CO_2, draft, proper rating, and coal and water consumed are allowed to run along unchecked and unnoticed.

If no attention is paid to the matter of feed water treatment and boiler scale, it will be found expensive. Many a boiler steams along with an eighth or a quarter of an inch of scale on its tubes, using perhaps 25 per cent more coal than is necessary. Many an engineer follows the obsolete scheme of dosing the boilers with a compound sold him by some irresponsible salesman at high cost and little result. The modern engineer uses the up-to-date scheme of analyzing his raw water frequently, testing his steaming boilers for alkalinity and chloride, and works under the supervision of some reputable feedwater engineer or specialist.

An economical operating engineer will see that a regular schedule of boiler inspection and cleaning is carried out. He will arrange to have boilers off the line at stated intervals, and while he looks after the details of the work, will expect a certain amount of supervision.

The lubrication of shafting and engines and the reduction of friction load are all matters which can receive attention with profit. Most oil concerns are glad to have their engineers examine any plant, and make a detailed report as to conditions found. It is seldom that such an examination and report does not reduce unnecessary friction load, quantity of oil and grease used, eliminate unsuitable lubricants, and save money.

Turbines with eroded and broken blades, condenser air leaks, reduced speed, poor power factor, and wet or improper steam supply build up expense and coal consumption imperceptibly but rapidly. These things cannot be detected on the instant, but regular observation of power records, frequent visits to the power plant, occasional judicious questions, and an interest in the power machinery will pay large returns in the long run. A little supervision will make a good engineer better, and if the man in charge is a poor engineer, this will become evident all the sooner. Many an inefficient operating engineer who has lost interest, and who is too dull to learn, is being retained in his position for sentimental reasons, with every one concerned seemingly unaware that, should the company double his salary, purchase him a mahogany desk, and promote him to a high-titled sinecure in the office well removed from the power plant, and where he could do no harm, there would be much money saved. Minute waste of material in process in the factory is noted and checked, but in the same factory, often enough, there will be a large waste of expensive fuel, shoveled at will by ignorant firemen into boilers unfit for service. A 1000-hp. boiler plant operated at 60 per cent efficiency, as is too often the case, which might just as well operate at 75 per cent efficiency, is costing from fifteen to twenty thousand dollars of unnecessary money annually. The chart given in Fig. 1 is helpful in this connection.

Power-Plant Operating Records

Continuous operating efficiency cannot be obtained from the power plant without some definite system of recording performance and costs. Power-plant records ordinarily vary in completeness from a much-thumbed book containing weights of coal delivered, to more or less elaborate sheets on which are recorded miscellaneous facts interesting to the operating engineer alone and which lead nowhere. Few such records are helpful in determining whether or not the plant is being operated in a reasonably efficient manner. The usual recourse in such cases is to employ an outside engineer to make an examination of the plant and a short and elaborate series of tests which determine more often what might be done under favorable circumstances rather than what

actually is done from month to month. Such examinations and reports have their value, but more necessary is some regular and continuous method of reporting data that will give a definite relationship between performance and cost which can be compared from month to month, and with outside sources of information. Such a report should give the ratio between cost and power and pounds or quantity of goods produced. It should contain such units as the cost of steam per thousand pounds, evaporation per pound of fuel, engine power per horsepower hour, electric power per kilowatt-hour, etc. Enough operating data should be recorded so that the report can be checked. With a series of such reports, perhaps covering performance for several years, information will be available which will show whether the power department is forging ahead or losing ground in operating efficiency. Faced with the necessity for enlarged capacity, replacement of obsolete units, or the possibility of turning to purchased electric power, the management has operating costs and data which will help determine the course. Any association of power-plant engineers, to derive maximum benefit from their meetings, must have some comprehensive form of continuous power report which will allow comparison of performance data and costs.

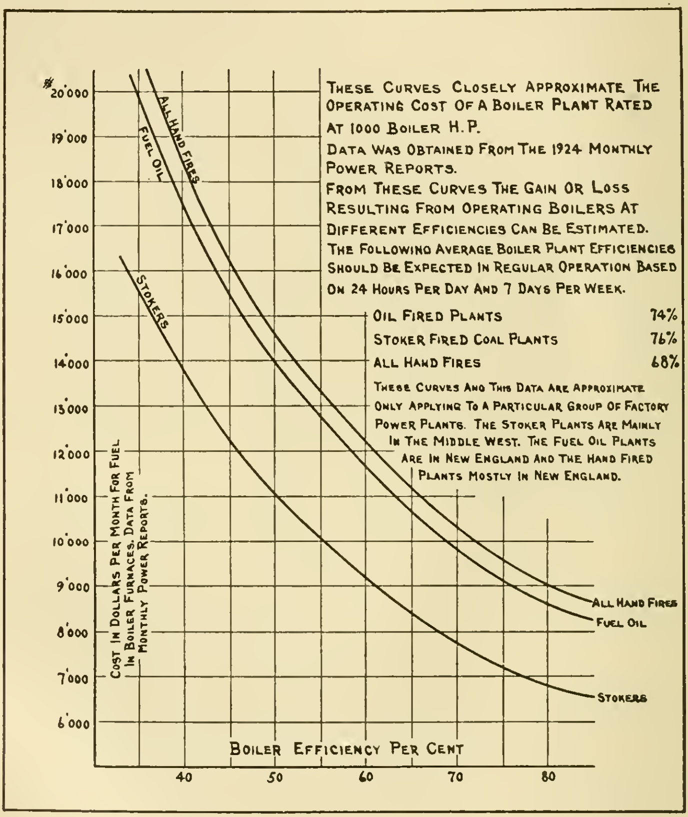

Fig. 1—Boiler Efficiency and Operating Expense
(Estimated from Power Report data, 1924)

Monthly Power Reports

Industrial companies operating several plants have found it advantageous and necessary to inaugurate monthly power reports for the reasons mentioned. One corporation operating several plants located in various parts of the country has used such a system of reports with beneficial results for several years. Such a report is shown as Fig. 2. It will be noted that the monthly power report shown is largely financial in character, with sufficient operating data so that it may be checked and power loads compared. Part of the recorded data come from the accounting department, where certain ledger accounts are broken down in such a manner as to make the collection of the necessary figures convenient. The remainder of the data come from the chief engineer's records. The report is made up usually by the plant engineer's assistant, although in many cases the chief engineer may attend to it. The amount of labor involved in making up such a report is not excessive, as the basic facts are kept in some form or the other in practically all power plants of any size, and the time employed is well expended on the part of the operating staff. The definite knowledge of the results of his operation and the costs of power generated tend to make the operating engineer more attentive to his duties and more interested in getting the best possible results. The fact that the report is to be scrutinized by the manager and compared with previous reports, or possibly reports of other plants in the same system, keeps him alert to economy of operation. He knows that his operating efficiency is usually charted, and that any falling off will be the subject of inquiry. Such a system of continuous power reports will save thousands of dollars annually, and few plants are too small for something of the kind.

The details of such a monthly power report as the one shown are readily understandable and very little explanation is required. It is intended to be complete enough to give a true picture of the operation as a whole, and is designed to be broad enough to cover plants with several classes of power apparatus, and at the same time definite enough so that the unit costs, such as fire-room labor, for instance, can be compared with those of other plants. The item of overhead expense or charges is one that perhaps requires the most study, and a method is shown in Fig. 3 which is used in many industrial power plants to distribute such expense as the proper proportion of the plant engineer's salary, the chief engineer's salary, depreciation of buildings and machinery, insurance, taxes, etc.

Accuracy of Operating Data

The majority of industrial plants keep power records of some kind, but another phase of the matter is too often overlooked, namely, accuracy of data. If the coal scales are incorrect, and the feedwater meter reads fast, the whole basis of costs will be wrong. Venturi meters have been found reading fifty and even a hundred per cent more than they should because of scale in the throat. Fuel-oil meters are seldom exactly correct, and steam-flow meters need calibration. The same is true of pyrometers, wattmeters, and all classes of power-plant instruments. No boiler plant should be considered complete without weigh tanks with which the feedwater meters can be regularly and conveniently checked. Such apparatus may consist of a pair of drums with a leveling pipe between them, holding a known weight of water at a certain temperature and emptying into a conveniently placed suction tank, or it may consist of a large tank holding enough for several hours or a day's run. In such tests correction must be made for temperature, and the flow must be continuous through the meter. Check tests of this character should be made reasonably often, from once a month to perhaps a minimum of once a quarter, de-

MONTHLY POWER REPORT

PLANT St. Jo
LOCATED Indiana
MONTH January 1925

SECTION 1, GENERAL DATA

PRODUCTION DATA

1. Pounds of Goods Produced 2'109'033 — Pounds Raw Material Used ____
2. Total Coal Burned Bitum. 4023.7 Per Ct. 100 Cost Mine 1.50 Frt. 1.56 Handling .42 Total 3.48 B. T. U. 11967
3. Total Coal Burned Anth. ____ Per Ct. ____ Cost Mine ____ Frt. ____ Handling ____ Total ____ B. T. U. ____
4. Total Oil Burned Bbls. ____ Specific Gravity ____ Cost Delivered ____ B. T. U. ____
5. Cost of all Power 25'256.62 — Same Less Charges 21'696.27
6. Cost of all Power from Accts. 19'826.48 — Total Man Hours, Productive 48'034
7. Cost of all Power per Pound Goods Produced .012 — Per Pound of Raw Material Used ____ Per Man Hour .526

OPERATING DATA

8. Factor of Evaporation 1.059 & 1.212 — Pounds Total Equivalent Evaporation 77'722'330
9. Temperature Outside Air, Average 19 — Average Barometer Reading ____
10. Temperature Flue Gas, Average 591 — Degrees Superheat, Average ____
11. Steam Pressure Gauge, Average 140 — Feed Temperature Fahr., Average 198
12. Temperature Water Entering Economizer, Average ____ — Temperature Raw City Water, Average 50

FEED WATER DATA

Grains per Gal. Carbonates 10 Sulphates 3.6 Alkalinity Carried 42 Chloride Carried 6.74
Chemicals Used for Treatment Caustic Soda — Total Pounds for Month 6608 — 15 Baume Sol.

SECTION 2, POWER PRODUCTION & TRANSMISSION DATA

POWER DATA	COST ITEMS	COST AMOUNTS: LABOR	COST AMOUNTS: Other than Labor	COST AMOUNTS: TOTAL	UNIT COSTS (Steam Per M Lbs. F. & A. 212°)	
BOILERS						
A Average Boiler Load 3'288	1. Tot. Cost Boiler Fuel*	x x x	14025.40	14025.40	Fuel	.181
B Lbs. Evap. 73'392'191	2. Other Operat'g Exp.*	4073.40	111.84	4185.24	F. R. Labor	.052
C Evap. per 12000 B. T. U. 9.145	3. Boiler R'm Auxiliaries*	82.24	20.56	102.80	Supplies	.002
D Evap. per Lb. Fuel 9.12	4. Total Repairs	415.56	527.39	942.95	B. R. Aux.	.001
E Equiv Evap. F. & A. 212° 9.66	5. Charges	x x x	1303.91	1303.91	Repairs	.012
F Boiler Efficiency 78.3	6. Total Cost	4571.20	15989.10	20560.30	Charges	.017
G Overall Efficiency 89.6					Total	.265
MAIN ENGINES	7. Cost of Steam Used	x x x	3348.91	3348.91	Main Engine	
H Average Load H. P. 985	8. Other Operat'g Exp.*	368.08	51.28	419.36	Power Per	
I Steam per H. P. Hour 21	9. Total Repairs	408.65	127.94	536.59	I. H. P. Hour	
J Total H. P. Hours 569'330	10. Charges	x x x	504.14	504.14	.00845	
	11. Total Cost	776.73	4032.27	4809.00		
AUXILIARY ENGINES	12. Cost of Steam Used	x x x	822.24	822.24	Auxiliary Engine	
K Average Load H. P. 164	13. Other Operat'g Exp.*	197.66	6.49	204.15	Power Per	
L Steam per H. P. Hour 24	14. Total Repairs	21.63	25.49	47.12	H. P. Hour	
M Total H. P. Hours 122'313	16. Charges	x x x	85.20	85.20	.00947	
	16. Total Cost	219.29	939.42	1158.71		
ELECTRIC GENERATORS	17. Cost of Steam Used	x x x	6236.77	6236.77	Generated	
N Average Output K. W. 1175	18. Other Operat'g Exp.*	219.45	43.62	263.07	Electric Power	
O Steam per K. W. Hour 25	19. Total Repairs	172.50	78.75	251.25	Per K. W. Hour	
P Total K. W. Hours 874'534	20. Charges	x x x	1122.87	1122.87	.009	
	21. Total Cost	391.95	7482.01	7873.96		
PURCHASED ELECT. POWER	22. Tot. Pub Service Bills*	x x x			Purchased	
Q Average Load K. W. ____	23. Other Operat'g Exp.*				Electric Power	
R Total K. W. Hours ____	24. Total Repairs				Per K. W. Hour	
S Average Power Factor ____	25. Charges	x x x				
	26 Total Cost					
WATER POWER	27. Cost for Water*	x x x	340.54	340.54	Water Power	
T Average Load H. P. 184	28. Other Operat'g Exp.	285.92		285.92	Per H. P. Hour	
U Total H. P. Hours 110'626	29. Total Repairs	71.55	20.33	91.88		
V Hours Operated 601	30. Charges	x x x	544.23	544.23	.0114	
	31. Total Cost	357.47	905.10	1262.57		

SECTION 3

Distribution and Use of all Live Steam Generated in Thousands of Pounds for Month.

(a) Total Live Steam Used for Power 37'136 M Pounds
(b) Total Live Steam Used for Auxiliaries 3'669 M Pounds
(c) Total Live Steam Used for Heating 1'467 M Pounds
(d) Total Live Steam Used for Process Work 30'501 M Pounds
(e) Total Live Steam Used for Losses 619 M Pounds
(f) Total Live Steam Used (see Section 2, Item B) 73'392 M Pounds

NOTES—* Items marked with Star form Total Charge to Power Expense as per Form
Total Repairs and Maintenance Charges on this Report should balance with Amount Charged to Dept.

Signed Nathan S. Fessenden
Factory Manager

Fig. 2—Monthly Power Report

INSTRUCTIONS ON MONTHLY POWER REPORT

TABLE OF POWER DEPARTMENT OVERHEAD ITEMS

		ADD THESE TO THE ITEM "OTHER OPERATING EXPENSE," LABOR ON THE POWER REPORT		ADD THESE ITEMS TO THE ITEM OF CHARGES "OTHER THAN LABOR" ON THE POWER REPORT				TOTALS
		DISTRIBUTION OF SALARIES		DEPRECIATION		INSURANCE	TAXES	
	VARIOUS KINDS OF PLANTS	M. M.	Chief Engineer	Machinery	Buildings	On Total Reproductive Value of Machy. & Bldgs.	On Tax Assessor's Valuation Machy & Bldgs.	
1	POWER PLANT INCLUDES	Per Cent of Entire Salary		On Reproductive Value from Appraisal Book				
	(a) Boilers	Distribute 20% of M. M's. Salary according to the amount of Connected Load	Distribute all of Chief Eng'rs Salary according to the amount of Connected Load	5%	4% Wood 3% Brick 2% Concr. Buildings	At about 1-10 of One Per Cent Consult Plant Manager	Assessors Valuation Times Tax Rate Consult Plant Manager	
	(b) Engines			5%				
	(c) Generators			5%				
	(d) Purchased Electric Power			5%				
	(e) Water Power			5%				
	(f) Inert Gas			5%				
2	POWER PLANT INCLUDES							
	(a) Boilers			5%				
	(b) Engines	Same	Same	5%	Same	Same	Same	
	(c) Generators			5%				
	(d) Purchased Electric Power			5%				
	(e) Inert Gas			5%				
3	POWER PLANT INCLUDES							
	(a) Boilers			5%				
	(b) Engines	Same	Same	5%	Same	Same	Same	
	(c) Generators			5%				
	(d) Inert Gas			5%				

NOTE—The above gives three typical groups of power units. Arrange yours in a similar way. To get the percentages for use in distributing salaries, proceed as follows: Say all the boilers are rated at 2,000 H. P.; all the engines, hydraulic pumps, service pumps, air compressors, steam end of turbines, etc., are rated at 1,000 H. P.; all the motors, lighting circuits, etc., connected to the plant generators rated at 1,000 H. P.; all the motors, lighting transformers, rotary converters, motor generator sets, and other apparatus connected to the public service or purchased power at 1,500 H. P.; all the load on the water wheels rated at 400 H. P.; the load made by all the inert gas compressors, motors or other apparatus rated at 100 H. P. Total, 6,000 H. P. Then boilers are charged with 33 1/3% of chief engineer's salary; engines 16 2/3%; generator 16 2/3%; purchased power 25%, water power 6 2/3% and inert gas 1 2/3%. Twenty per cent of master mechanic's salary distributed the same way

FIG. 3—INSTRUCTIONS ON MONTHLY POWER REPORT

pending on the character of the plant. Fuel-oil meters should be tested frequently in the same manner.

Coal scales should be checked with standard weights and care taken that they are swinging freely on their knife edges with no coal dust and dirt in the way. Steam-flow meters should check reasonably well with feed meters, and the matter of blowdown should receive careful attention. Many operators attain high boiler efficiencies due to the fact that they neglect to deduct the blowdown. The matter of coal testing is important. The operator needs to know that he is getting the most suitable fuel for the large amounts of money expended. All coal looks more or less alike, and the heat units contained in it cannot be seen. It is also important that the engineer know the thermal units in the coal that he may calculate his boiler efficiency correctly. The operating engineer may be struggling with the smoke problem, unaware that he has coal of excessively high volatile content, which a test would reveal. All power-plant instruments should be checked regularly so that their records may be true ones and the engineer may have accurate information on which to base his reports, and to guide him in the operation of his plant.

Aids to Economy

There are many schemes which are used with more or less success to keep before those interested the operating status of the power plant. Probably the simpler the scheme, the greater its success. If some sort of gage could be devised which would record boiler operating efficiency on a moving chart, it would be of great value. Perhaps the best substitute is a monthly efficiency and evaporation chart like that shown in Fig. 4. Such a chart shows the tendency, whether to improvement or to a falling off in efficiency.

There are public-service stations in which operating data are regularly assembled, figured, checked, and results in the hands of the chief operating engineer within two hours of the time the instruments are read. There are plenty of industrial plants, however, where a "yearly check-up" is considered good operation.

Many factory offices are provided with recording flow meters and steam gages so that load changes can be followed as a matter of interest. A chart covering fluctuations of boiler efficiency and evaporation carefully plotted, covering a year or two with fair degree of accuracy, has far greater possibilities when it is considered from the standpoint of money saving. Many operators have difficulty in appreciating the effect of boiler efficiency on the use of coal and the factory expense. A curve sheet like that shown in Fig. 1 will often assist in the promotion of plant economy.

Simple, inexpensive schemes like that shown as Fig. 5 may be devised to keep the more or less non-technical management in touch with what is going on in the power plant and help it to differentiate between good work and poor results.

Where it is possible, valuable comparison can be made between a number of plants in the same system, or through co-operation between plants in the same neighborhood or between the plants operated by the members of some association of plant engineers, as is not unusual. Such comparisons tend to increase operating efficiency, as it is often found that what was considered good operation will not bear comparison. Such curves are shown as Figs. 6 and 7.

The Factory Power Plant

The power plants found in factories are changing in character rapidly. Twenty-five years back the fire-tube boiler and automatic engine were more or less universal. Today high-pressure water-tube boilers operated at high ratings are replacing the old horizontal-return tubular boilers. Where the engine remains in the larger plants, it has been supplemented with the low-

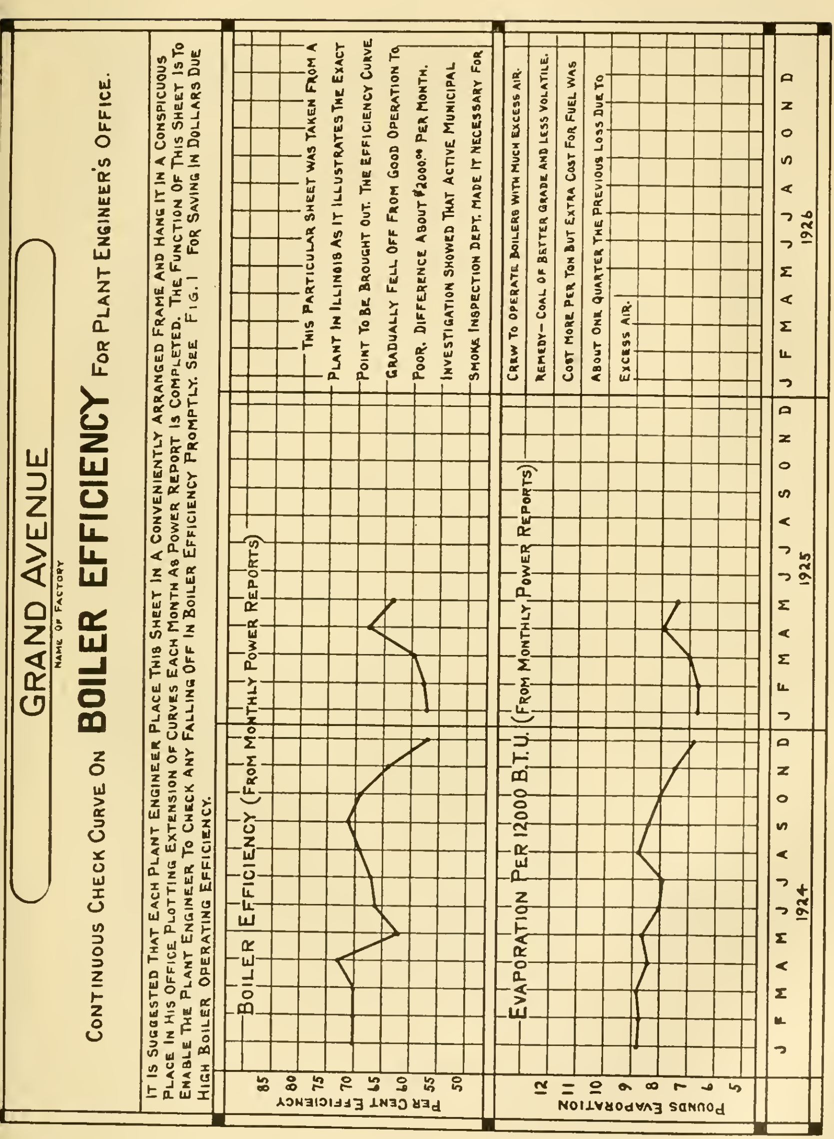

Fig. 4—Continuous Check Curve on Boiler Efficiency for Plant Engineer's Office

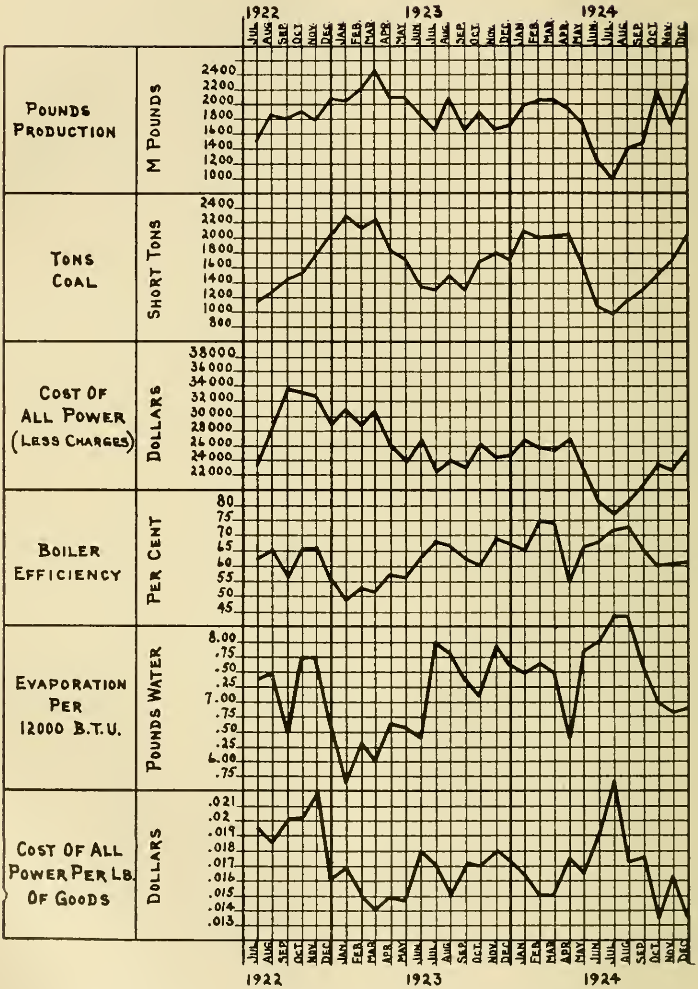

Fig. 5—Factory Manager's Power-Plant Operating Data

pressure exhaust turbine which generates electricity to drive the factory machinery not in the immediate vicinity of the engine room. Frequently the engine is superseded by the high-pressure turbo-generator whose low water rate and absence of friction load and transmission losses are found profitable. In many cases the boilers only remain to generate process and heating steam, while the motive power is provided by electricity from public-service stations, coming to the factory over high-tension lines and being stepped down to safe operating limits at the factory switchboard. Each factory has an ever-present problem to determine the most economical method.

The solution of the problem of economical power generation must be approached with care, as changes usually mean considerable investment. Operating costs in detail should be available over a considerable period before extensive changes are contemplated. It must be ascertained first that the present power plant is being operated to the best advantage. Poor boiler operation results in high cost of steam and high cost for motive power per unit. An attractive figure from the public-service company may in effect be the comparison of their highly efficient operation with an unnecessarily poor grade of operation in the local plant. A favorable figure from the outside power company may result, for instance, from a lack of understanding at the factory of the value of the exhaust steam used for heating and process work. There are many cases where purchased power is the most economical way out, but there is no general rule, and each case must stand on its merits. When the question of plant enlargement is under consideration, the matter of public service power, if available, should have most careful attention, as then the factor of new investment is prominent. Then enlargement of prime movers will probably mean additional boiler capacity, enlarged steam mains, new coal-handling apparatus, and similar expense, which may result in an unfavorable unit cost.

Public-Service Power

In recent years numerous large electric generating units have been constructed all over the country operated by steam and water power. Long high-tension transmission lines are in evidence crossing the states for considerable distances which will be found tied into various public-service electric plants located in industrial centers. Remote localities which have a surplus of hydro-electric power send this surplus at high voltage to the cities and deliver it through local public-service stations to the industrial plants of the vicinity, supplementing the power generated by the local station. This practice is so universal and so constantly increasing that the public-service stations are reaching out for an increased market for their output. The consequence has been a gradual dropping of public-service rates, until a point has been reached where any industry which generates its own power, if located where public service is available, has reason to investigate carefully the comparative costs of its operation to justify its present practice. This does not mean that no private plant can be operated profitably, but rather that many such can investigate the possibility of public service to advantage, and that few can afford to neglect careful study of how they stand with reference to this matter.

There are many general reasons why an old type of power plant often can be supplanted by outside power with profit, and the first important requisite for an investigation is the existence of reasonably accurate data which tell the story of present and past performance. It must be shown first that the plant under consideration is being operated at reasonably high efficiency, or what changes are needed to bring it to that point, and the probable cost of such changes. Only after that is done can a reasonable comparison be made with

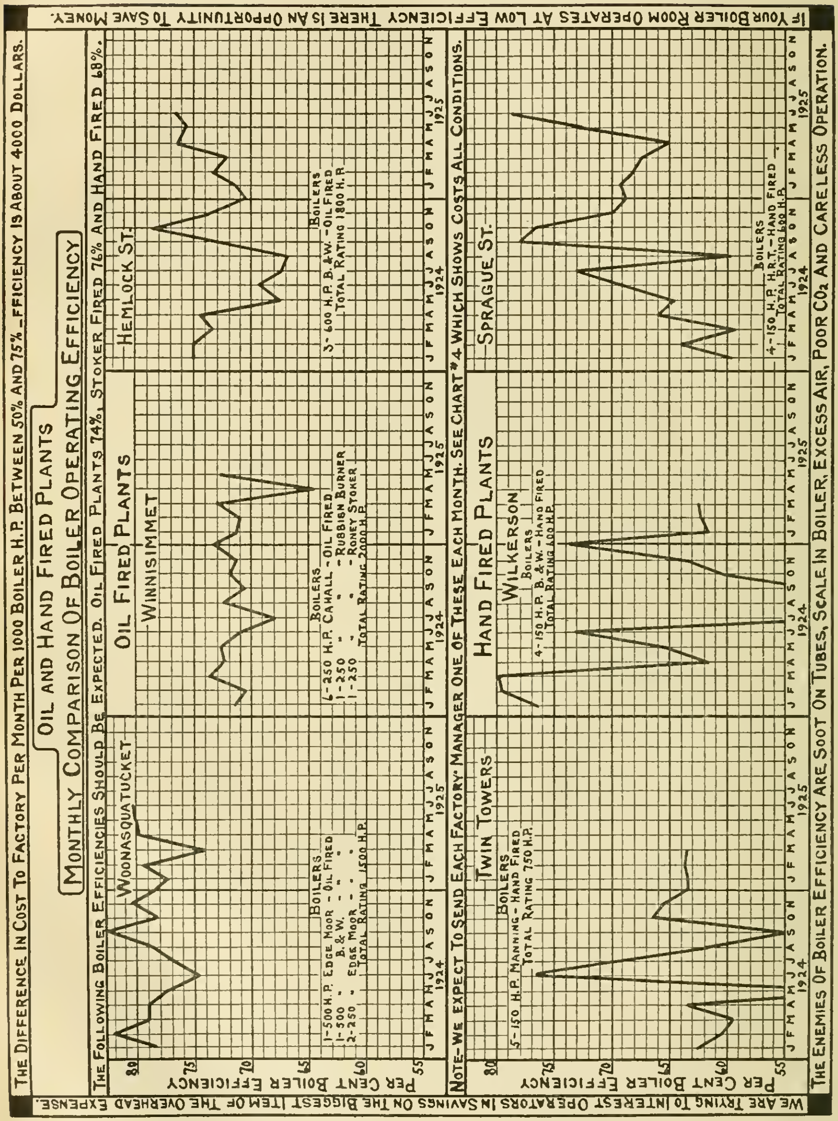

Fig. 6—Oil and Hand-Fired Plants—Monthly Comparison of Boiler Operating Efficiency

costs which would be in effect with public-service power. Many plants have several small engines distributed through the factory with long transmission lines of piping which could be supplanted profitably by electric motors. Many prime movers are old and inefficient, with high and frequently unsuspected friction loads. Many power plants are so arranged that a large number of operating engineers are required to look after the various units. In many cases the load factor is comparatively small and the friction load considerable, and the advantage of electric drive — which furnishes power at the point where it is used with less friction loss, and which can be shut down when the power is not needed—should be carefully considered. The element of safety should not be neglected. Compensation costs are carefully studied today and they are considerable in all industries. State laws are becoming more stringent continually and it is generally recognized that the electric drive, which lends itself readily to proper safeguarding, quick stopping, and ready control at all times, is an asset too important to be overlooked.

The operation of the boiler plant usually is the source of the greatest item of expense, and here again consideration of public-service power is important. Industrial boiler plants are quite generally heavily loaded, at times beyond capacity. Many are obsolete and unduly expensive to operate. Many plants are at the point where every boiler is needed on the line perhaps twenty-four hours a day, with little opportunity for proper cleaning or ordinary care. Probably the boiler plant must be enlarged in the near future, or perhaps entirely rebuilt. In such cases it will be advisable to consider outside power before entering into a program of considerable capital expense. Often privately operated generators are overloaded, and driving speeds unavoidably reduced, with increased and expensive amperage or current requirements due to the reduced driving speeds. This, too, calls for a consideration of the whole matter and of possible changes which will result in a more favorable unit cost.

The introduction of public-service power may mean the location of a transformer on a pole adjacent to the smaller plant or, in the case of a large industry, the construction of a small substation or operating unit in the factory yard. It usually results in the ultimate elimination of the old power-generating units, more room for manufacturing, simpler transmission, and the avoidance of considerable labor trouble.

The factory substation in an average industry, say, of a thousand kilowatts capacity, often consists of a small brick or concrete building with an outside shelter for the high-tension transformers, which are usually numerous enough so that the load can be split, including one transformer for ordinary loads, another for peak conditions, and perhaps a third smaller unit for night loads, holiday, or partial shutdown periods. Mains come into the substation from underground public-service conduits to the high-tension switchboard, which is carefully enclosed, protected, and accessible ordinarily only to the public-service employees. These boards for incoming high-tension current are provided with the necessary wattmeters and recording instruments so that the quantities of power used and demand are easily read. High-tension leads run from the incoming switchboard to the transformer control board by means of which the transformer capacity can be adjusted to the needs of the factory. From this second switchboard leads run to the busbars of the distributing board, from which power is sent out to the various motor units located at various points in the factory itself. This distributing board also carries the lighting circuits, and all circuits are supplied at the board with the necessary wattmeters, control instruments, voltmeters, ammeters, power-factor meters, etc., so that the whole is under the control of a single operator who is not only able to

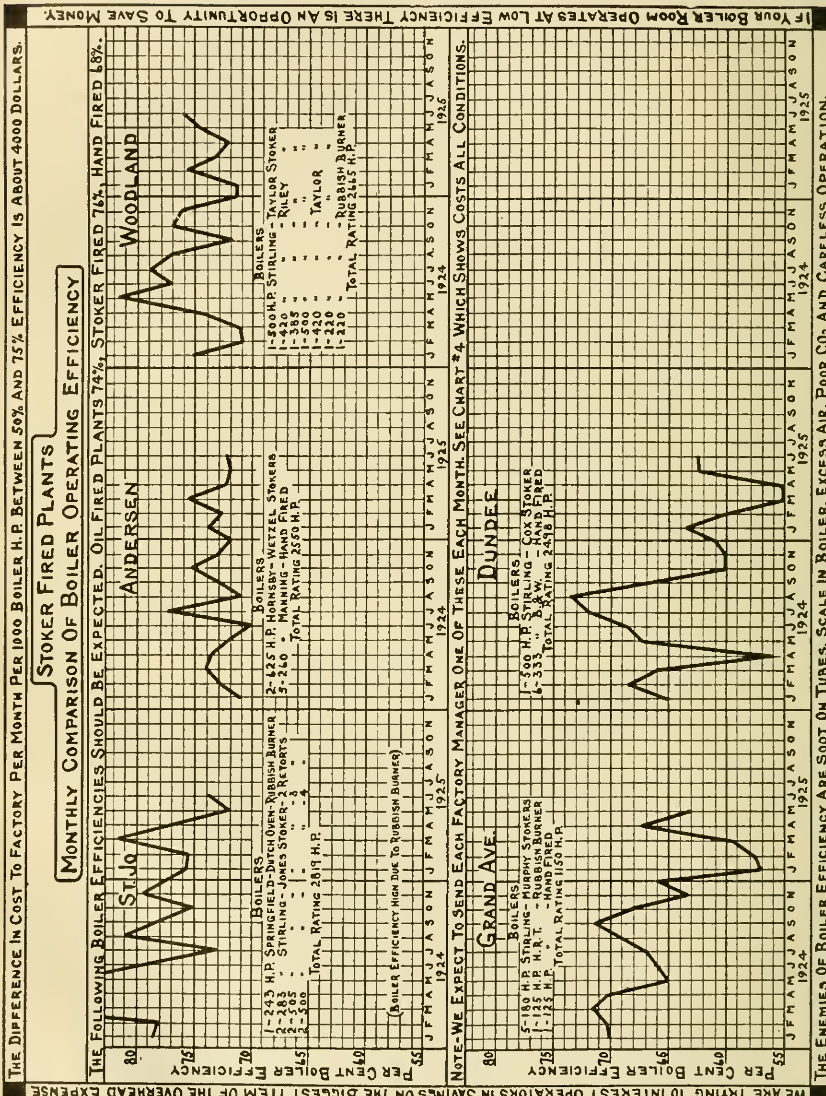

Fig. 7—Stoker-Fired Plants—Monthly Comparison of Boiler Operating Efficiency

handle the situation efficiently at all times, but to keep a careful record of power consumption in the various departmental circuits. Most industries require a considerable supply of direct current to operate variable-speed motors driving elevators and variable-speed machinery. To serve this requirement the substation is generally provided with one or more rotary converters or motor-generator sets, which are also under the control of the substation operator.

The power feed lines leading from the substation to the motor units in the factory can be conveniently arranged and supported out of the way, and as a general thing are a vast improvement over the old scheme of transmission pipes, lines of shafting, and inconvenient and expensive belt transmissions which robbed the factory of light, caused excessive temperature in work rooms, were a constant source of danger to the workmen, and are better eliminated.

As a matter of interest it might be stated that a substation such as has been described has cost in several cases about twenty-four dollars per kilowatt capacity.

While it is not true that in every case an industry can turn to public-service power as a solution of its troubles, in many cases the subject can be investigated with profit. Where considerable quantities of water power are available or where large units are efficiently operated, the public-service rates possibly may be met successfully. In most cases, however, a critical comparison can be made profitable, allowing the public-service engineers ample facilities to prepare their case and making sure that the statement of the factory engineer is based on sufficient and accurate operating data.

As a matter of principle, few industries today care to go very far outside their own lines. Very few find it profitable to build their own machinery; few rubber mills, for instance, find it profitable to maintain large machine shops to manufacture the numerous molds they use in their business. Such work is largely done now by outside contract shops that make it their specialty. The rubber mill finds it profitable to confine its operating capital to the production of rubber goods; the sugar refinery, to the production of sugar; the foundry, to the production of iron castings, etc. It is becoming more and more evident that the production of power is a specialty and that such power often may be purchased with profit from a large outside source specializing in that commodity and operating large units at a point of efficiency impossible of attainment in a comparatively small unit.

Periods of shutdown cause considerable financial loss in certain industries, particularly where large amounts of raw stock are in process at all times. Unfortunately experience of some years with public-service or central-station power has shown that there will be short periods when power is off due to electrical storms, accidents to transmission lines, and station troubles. There have been complaints of fluctuation in line voltage due to overloaded transmission lines which must be taken into consideration also.

These matters may not prove to be serious factors in the majority of industries, although they might give rise to comment in some of our industrial power plants which claim freedom from shutdown for periods of many years.

While it is the usual thing to eliminate the possibility of protracted shutdown periods as far as possible by the use of duplicate transmission lines nevertheless the matter is important enough to deserve most careful consideration by central-station engineers, as the possibility of interruptions to the service, however brief or infrequent, is often the deciding factor regardless of other elements.

Conclusion

In conclusion, it might be stated again that these paragraphs were written with the thought that they might be helpful to the great number of our smaller in-

dustrial plants, that they might let a little light into that corner of the factory which is too apt to be shrouded in mystery to the non-technical man in the office. The endeavor has been made to show what other industrial plants are actually doing in the way of power costs and to indicate how good operation can be known and poor operation remedied. Some of the earmarks of both good and poor operation have been pointed out so that when the manager steps into his boiler room or engine department he will perhaps be able to view what is going on with better understanding, and when he questions his engineer as to power conditions he may do so with more confidence. It has been suggested that before enlarged capacity, changes in machinery, or possibility of turning the plant over to the public-service corporation are discussed, it should first be ascertained that the present plant is operating at maximum efficiency, using up-to-date methods. It has been also suggested that the day of the old-line steam engineer who knows nothing of modern methods of figuring and operating is well past, and that many such can be supplemented profitably with operators of better understanding while giving every consideration to the older men. Examples of modern power-plant reports have been shown with explanations of the function they serve and of their value as a basis of comparison from month to month and between different plants. It has been shown that such power reports, to be of value, must give definite cost data which will be comparable and which will help the manager in making up his estimates, and in making power plant studies, and will tell him whether the tendency is toward improved operation or otherwise. It has been suggested that no operating or power data are of value unless the instruments used in the power house for collecting the facts are correct. Few such instruments will remain accurate for any length of time, and all must be checked and calibrated with regularity and frequency.

Certain charts and curves that may be used as aids to economy and indicators of operating conditions are shown. Such schemes are valuable in that they picture conditions in so simple a way that the meaning is readily grasped, yet they help both the manager and the engineer to maintain the plant on the highest possible plane of efficiency.

Some little space is given to the matter of public-service electric power. It has been suggested that the advantages of this service should be given careful unbiased consideration in many places, that power generation is a high-grade specialty which every industry cannot undertake successfully, and that the operation of private plants in some cases is not justified.

ROUND-TABLE DISCUSSION

QUESTION: I would like to ask Mr. Larkin if he has any rule about the use of stokers in place of hand firing. What size plant do you draw the line on?

WM. H. LARKIN, JR.*: We never have adopted any very definite rule because of the fact that we have a lot of old plants, and it is very difficult sometimes to get money to revamp a plant as you would like. Probably we should not think of putting a stoker under any boiler much smaller than 250 hp. We have a lot of Edge Moor boilers about 250 hp. Where it comes to small boilers like that, we favor pulverized coal at the present time. I think there is no particular rule we have followed, simply because of the fact we are dealing with a lot of diversified plants, all kinds and types of boilers—from Manning and Cahall boilers to Stirlings—and no rule has ever been exactly applicable. But I should say that if you tried to put mechanical stokers under anything smaller than 250 hp. you would have difficulty in justifying them.

QUESTION: Along this same line I would like to ask Mr. Larkin if he has any line which he draws between fire-tube boilers and water-tube boilers in regard to size of tubes.

MR. LARKIN: Why, yes. Of course we are blessed with a lot of fire-tube boilers, as is everybody else, but we have drawn a line in this way: if we ever buy any boilers, or have a chance to get rid of the fire-tube boilers, we shall, in all probability, never have any more unless the plant is very small or expediency requires that we use the least expensive arrangement. Most of our plants are large enough so that high-pressure water-tube boilers are quite suitable. In our larger plants we are hoping to go to the higher pressures. We have a plant under consideration now to be designed with 400 lb. pressure boilers. Of course that is practically impossible with fire-tube boilers. We have a small plant we are rebuilding now that had nine return-tubular boilers, 150 hp. each, which we expect to replace with three boilers of the water-tube type carrying about 200 lbs. pressure. I think that our conviction is pretty well crystallized on water-tube boilers, high pressures, and high ratings. Of course fire-tube boilers will seldom meet that specification.

To return definitely to the question of size of fire tubes: there seems to be no general rule. As a matter of expediency, manufacturers of H. R. T. boilers use 3″, 3½″, and 4″, mostly the latter two sizes. The choice seems to lie between excessive draft loss through the boilers, or excessive deposit of soot in the tubes due to cooling and slowing down of flue-gas speed of flow, through large fire tubes, with resultant inefficient heat transfer due both to the dirty surfaces and the low gas velocity. With the water-tube boiler the arrangement of baffles can be made to avoid much decrease of flue-gas velocity by reduction of areas as the gases flow from one pass to another, thus keeping rate of heat transfer more nearly constant.

H. B. EMERSON†: I believe we will all agree, from what we know ourselves and from what we have learned from these various papers, that every individual plant has to be laid out according to its individual conditions.

There is, however, a question of charges and credits which I feel can be discussed to good advantage. Regard-

*Power Engineer, General Division, United States Rubber Co., New Haven, Conn.
†Superintendent, Mechanical Dept., Arlington Mills, Lawrence, Mass.

ing the charge for extraction steam, there seems to be a variance of opinion; and I thought this would be a good time and place to bring out expressions, and try and obtain, if possible, some understanding of the actual cost of extraction steam and to what it should be credited. Some people are charging out steam (whether extraction steam or direct from the boilers) at the same price; that is, crediting the particular power unit from which the steam is extracted with the full cost of the steam extracted from it. There are others who are charging out their extraction steam on a B. t. u. basis and crediting the power unit with the difference between the B. t. u. of the steam entering and leaving the unit. There are others who use their entropy diagram and charge out that way, crediting the power unit with the difference in the quality of the steam entering and leaving the unit.

I should be pleased if we could discuss what the proper basis is. You may say that it will differ in different plants. It may differ, perhaps, in the mind of the individual owner. He may feel that one process can stand a greater charge than another, and simply put the burden of the load on that; but the point that I would like to have brought out is, is there not some proper basis for the charge for extraction steam and a proper credit due the power unit from which it is extracted? I would be glad to hear the views of some of the others on this subject.

Ernest Pragst*: I have been asked on several occasions to investigate the advisability of generating power where part of the steam produced was to be extracted from the prime movers for use in the plant's processes, and in each case this same question has arisen. Unless we approach the problem in a rational manner, an erroneous conclusion will inevitably ensue.

I will first present as an example a case in which such a conclusion has been reached. The engineers of a steel plant were studying the relative merits of purchased power and power generated within their plant. When I reviewed their estimate of production cost—most of their power was to be generated from blast-furnace gas—I found that they had charged against the cost of generation, gas at a cost equivalent to that of an equal amount of coal. Now, that was all very well for internal bookkeeping, but it led to an inaccurate conclusion in this particular case. They had decided that it was more economical to purchase power. Their figures clearly showed it. The fallacy in the reasoning was this: They had charged the estimated value of the gas to the estimated cost of power generation and credited the blast-furnace operation with a like amount. If power had been purchased, the gas would have been lost, and so no credit could have accrued to the blast-furnaces. In other words, viewing the operation of the plant as a whole, they would have lost approximately the amount at which the blast-furnace gas had been valued. When the problem was properly studied—the plant considered as a whole—an opposite conclusion was reached.

Unless we are careful to pro-rate equitably the cost of steam between power generation and process work in stations employing non-condensing or extraction machines, like errors are probable.

I have this suggestion to offer: Let us charge the turbine-generators with all heat, above water at condensate temperature, entering them. Then, credit them with all heat (also above water at condensate temperature) in the steam extracted (or exhausted into the process steam system in the case of non-condensing machines). The remainder will be the amount of steam entering the turbines truly chargeable to power generation. In a like manner the processes should be credited with the heat re-

*General Electric Co., Schenectady, N. Y.

turned by them to the boilers. All steam required by auxiliaries, which serve only the turbine-generators, should be charged against power generation. Those auxiliaries, serving both the turbine-generators and processes, should have their steam expense pro-rated. On this basis we should make, I believe, an equitable division of the expense insofar as it applies to steam.

QUESTION: I would like to ask Mr. Larkin what he calls high rating on a boiler?

MR. LARKIN: In industrial plants we think if we get 200 per cent rating we are doing pretty well. The average industrial plant seldom runs long at over 150 or 160 per cent. Of course when you talk about public service plants, 350 per cent rating is quite the general thing, but I think you will find very few industrial plants that go very much over 200 per cent.

I should like to make one suggestion. We have studied this question of charge for the cost of exhaust steam, or the value of exhaust steam, and the value of bleeder steam. Our thought in that line has always been this, that the value of exhaust steam is equivalent to the cost of the back pressure put on the engine. In other words, your engine is a certain thing when it is running condensing, and it is another and very different thing when it is running against back pressure. The difference in the cost of operating under the two conditions is the value of the exhaust steam.

With the bleeder turbines, such as we [illegible]e at one or two of our larger plants, [illegible] have gotten at it the same way. The [illegible]ter rate is one thing when the tur[illegible]e is running condensing, without any [illegible]am being bled off. The water rate [illegible] a very different thing when you are [illegible]ing steam from it. You are not [illegible]ly taking a certain amount of steam [illegible]ich passes through the turbine, but [illegible]u are also penalizing the turbine on its [illegible]n water rate as a generator of power.

C. W. CONRAD*: I am an advocate of using the B. t. u. basis. The plant with which I am connected generates super-heated and saturated steam. In order to get a definite basis for distribution, we convert all of our steam to B. t. u.'s. Instead of using 1000 lbs. of steam, we have 1,000,000 B. t. u.'s for a unit. Our plant is a paper mill, and naturally we use lots of process steam. We have seven non-condensing engines supplying exhaust steam, a bleeder turbine, and we use some high-pressure make-up. We charge to each paper machine, or to each steam user, the million B. t. u.'s used during the period of comparison—a month, for instance. I think that, as Mr. Larkin said, there is some argument for charging steam on a basis of the additional power required or heat required due to putting on back pressure, but where we can use all of our process steam for drying paper, I think the only fair unit we can use is the B. t. u.

W. A. DANIELSON†: In Cincinnati the officials of the leading hotel were undecided whether they should buy power or generate it in their own plant. Extensive alterations had just been completed which would require a slight addition to their plant. Under an arrangement with the local power company, they were to run for one year buying power from the power company and making the steam required. At the end of the year they were to compare the total cost of purchased power and steam made with the cost during previous years when they had made both. I do not know the outcome, but it shows that in the last analysis one must ascertain the cost of steam and power for the year, and of steam alone, to find what the power generating cost amounts to.

A. W. BENOIT‡: One thing which has been touched on a little, and yet about which not much has been said, is

---

*Plant Engineer, Bird & Son, East Walpole, Mass.

†Major, Construction Service, Quartermaster Corps, U. S. A.

‡C. T. Main, Engineer, Boston, Mass.

the use of the hot water which we get from the condenser on turbines. We, who are interested particularly in the textile industry where large quantities of hot water are used, find that we can install bleeder turbines and extract the steam for process work at about 15 lbs. pressure and use it in various ways. The remainder of the steam is turned into the condenser, and by sacrificing the vacuum more or less, the cooling water can be raised to about 120 degrees. This water is put into storage tanks to be used as it is wanted, because the demand for water, of course, is very intermittent. In that way I know of plants where, with the exception of the last hour of the day, practically all the steam that goes into the turbine has been used for process work, and the cost of power is measured by the radiation losses from the turbine and the overhead on the equipment, except for the small amount of heat that is wasted in the hot well in the latter part of the afternoon. This is a very common condition in the textile industry, and under these conditions they cannot usually afford to purchase power.

Frederick M. Gibson*: There has been a great deal of discussion in certain circles as to whether or not automatic regulation of stoker speed is desirable or worth the price of the regulator. I am going to ask all those who think it is worth the price of the regulator to raise their hands. The question is, do you get sufficient value out of speed regulation of a stoker to warrant the cost of the regulator? (One hand is shown.) Those that think it is not worth the cost will raise their hands. (One hand is shown.)

Mr. Chandler†: In the discussion this morning on extraction steam, I do not think the point was brought out quite clearly that there is an economic point whereby the back pressure can be regulated. In other words, in the case of an ordinary industrial plant that has an initial steam pressure of, say, 150 to 175 pounds, what is the highest back pressure at which it would be economical to put in some sort of bleeder outfit? If you have a small range between your initial pressure and your back pressure, it would take a very large unit, of course, in order to get work done. Now, is there any limit that has been worked out to the range that gives you an economic machine to put in?

Mr. Pragst: Mr. Dickinson has shown us a number of extraction-type turbines. Within a wide range of limits the designs lend themselves to extraction operation at almost any pressure below the initial pressure at the throttle. Obviously, as the extraction pressure approaches the initial pressure, the amount of power available from the extracted steam decreases, and decreases rapidly. For example, there is about as much power available—I am speaking just roughly—between atmosphere and 28-inches vacuum, a range of 14 pounds, as there is between 200 lbs. absolute pressure and atmosphere, a range of 185 lbs. When we come down in pressure, the available power per pound difference in pressure increases very materially.

Mr. Chandler has specifically suggested, if I remember correctly, 175 lbs. initial pressure and 100 lbs. extraction pressure. An extraction machine to meet this condition is entirely feasible and can be evolved from the general types Mr. Dickinson has shown. One cannot say offhand that such a machine will or will not be economically desirable. I can say, however, that there is not much energy available between the pressures suggested. Specifically—I am speaking in general terms—the available energy between 175 and 100 lbs. pressure is but 13 per cent of that between 175 lbs. and 28 inches vacuum. From this a rough measure of the electrical

*Plant Engineer, American Sugar Refining Co., Boston, Mass.
†Plant Engineer, Walter Baker Co., Ltd., Dorchester, Mass.

output by a turbine-generator from the extracted steam can be had.

One of the limitations in extraction work is that if we design our turbine for much extraction, the high-pressure end must be made much larger and the low-pressure end smaller than required in the case of a simple condensing machine, if we are to have an economical machine. If it is necessary to operate such a machine at rated mechanical or electrical output with a reduced extraction steam withdrawal, then the low-pressure end will become congested, with a consequent impairment of the machine's economy. A compromise must usually be made. Now, I cannot give a general rule, or say offhand just what balance should be struck in a given case. Each must be studied on its merits. There have been cases where it has been found desirable to design for the extraction of almost all steam entering the throttle and seriously sacrificing non-extraction economy in doing so, but such cases are few. I should say that it is practicable to extract as much as 75 per cent of the steam entering the throttle without seriously impairing the efficiency of a well-designed machine. This, of course, is a very general statement.

Have I answered your questions?

Mr. Chandler: Not quite. The question I had in mind was, how high a back pressure could you design a turbine for and not make the expense of the turbine out of all proportion to the saving?

Mr. Pragst: The price of a turbine-generator of the kind Mr. Chandler has in mind is not disproportionate when contrasted with that of a straight condensing machine. As the back pressure is increased the flow for a given electrical output increases, but the volume of the steam per unit of weight decreases. This means that, although we need a large throttle and entrance ports, the number of wheels, or stages, can be reduced to one or two, and the exhaust will be quite small because the steam will leave it at relatively high pressure and, so, will be of small volume. We have built two 1000 kw. machines designed to operate with 75 lbs. back pressure. I believe they are now operating in a New York sugar refinery. No serious problems are involved in building such machines. Does that answer your question?

Mr. Chandler: Yes, thank you.

Mr. Gibson: Assume that a boiler with standard baffles is equipped with poured baffles resulting in an increased boiler efficiency of 3 per cent. If that boiler is working in conjunction with an economizer, will the combined boiler and economizer efficiency be increased by 3 per cent or less? Is there any one present who can answer that question?

Pell W. Foster, Jr.*: The Chairman, Mr. Gibson, has suggested the function of an economizer in acting to maintain high over-all boiler efficiency. As the efficiency of a boiler decreases, the temperature and weight of the gases leaving the boiler and entering the economizer increase. The economizer, therefore, does more work as the boiler becomes less efficient due to the greater temperature difference between water and gas, and also to higher gas velocities. It follows, therefore, that as the efficiency of the boiler itself decreases, the efficiency or performance of the economizer is improved.

Let us assume that the difference in efficiency of a boiler operating at 100 per cent of rating as against 250 per cent is 4 per cent. At the higher load the gas drop through the economizer and consequent water rise will be greater. For this reason the combined efficiency of boiler and economizer would probably be only 2½ per cent lower at the higher rating.

*New England District Manager, Power Specialty Co., Boston, Mass.

0

Industrial fuel and power : papers and discussions presented before the Affiliated Technical Societies of Boston, December 10 and 11, 1925. -- Boston, Mass. : [Lawrence Press, 1925?]
105 p. : ill. ; 23 cm.